HOUSE ORGAN OF Q-ALLOYS "To Be Sure" GENERAL ALLOYS COMPANY

EDITED BY [illegible] PRESIDENT

ALLOY PROGRESS

Bright Spot in Metal Progress

ETAL SHOW UMBER

...os of nearly three hundred people, ...er at the National Metals Conference, ...ity Gits, grace these six pages. I believe ...personalities dominate technologies,— ...s show and the industries are man- ...that the men mean most in human ... If I can't interest you, you won't ...pay more attention to my stuff than you ...to the also-ran alloy advertising.

METALLURGISTS and Executives are just ...grown-up-kids. You should have seen ...here wrought by 10 gross of Q-Alloy ...shot. Crack-shots hit some tender spots, ...rough-spots," with pot-shots at bare ... The prime sex interest at the show ...U. S. Steel's Puppet-Show, at the other ...of the Puppets' strings. The great ...show, being humanized by Ben Fairless ...into faction, reveals its warm palpitat- ...ing pet through Tony Sarg's Marionettes, ...ing the Perils of Peddling Steel. ...Showmanship! *Tom Girdler put on ...show in Youngstown, too.*

...Is a Salesman a metallurgist, and ...not a Metallurgist *not* a salesman has ...selling steel buyers for years until ...Steel opened two suites at the Am- ... The one on the third floor was ..."Metallurgists Suite 317, Sales De- ...on 11th Floor." The prospect had to ...he was metallurgically, or just so- ...wisely. Those in doubt made both ... some steel company wants to make ...at the next show, let them present ...McCarthy as "Vice Pres. in charge of ...," just *another dummy on the Sales ...Exec.*

...about half of the pictures, mainly ...ds," night-life, puppets, etc.; the ...fessional stuff is by Rex Hardy, Jr. ... and Fred Hess & Son of Atlantic ... were so busy at the show we forgot ...k a principal exhibit, carburizing ...the largest heat-treat which last ...cause they are lined with a metallic ...to retard carbon penetration. (HHH. ... 2,088,593 and 2,088,594.

...like reprints of this or any other ... of ALLOY PROGRESS, we'll gladly ... on request. To the first ten people ...tify one hundred or more pictures ...round pails of H.H.H. Timber Edge ...ney.

...LARENCE HEFFNER, blind, Chemist ...the Biddle Institute, told one on a ...recently married. "He scratched ... half way through a hair mattress ...he discovered his wife was in the ... If your picture is in this issue, ...your letterhead for one of those ...Q-Alloy pipes.

...TEEN years, consecutively, General ... have been the largest exhibitors in ...at the steel shows, and have used ...AM and A.S.S.T. advertising than ...*combined.* This year the G.A. ...contained three-fourths of the alloy ...at the show. 90% of the alloy ..., 35% of the new engineering de- ...servative statements, *ask any visitor.*

Q-ALLOYS THE QUALITY NAMES IN ALLOY FOR HEAT CORROSION ABRASION X-ite

FOUR electrically operated working models of new furnace mechanism were shown, our latest super-corrosion-resistant alloy GENLOY introduced, and stainless steel and castings for the process industries extensively exhibited. Fifteen G.A. men were kept busy. Space limits us in this issue to exposition of furnace mechanism, only one department of our business, but we solicit your inquiries on any alloys to resist heat or corrosion.

BILL BLAIR, Engineering Executive, Boston, and Walter Hazelton, Sales Engineer, Detroit, both received sentences in Matrimony recently, which reminds us of the letter received by Johnson & Johnson:—"Since the responsibility is divided, we shall name the twins Jay & Joy." Patent claims have been allowed on our new spiral combustion tubes with more area and higher heat liberation. Timken is building roller bearings for watches.

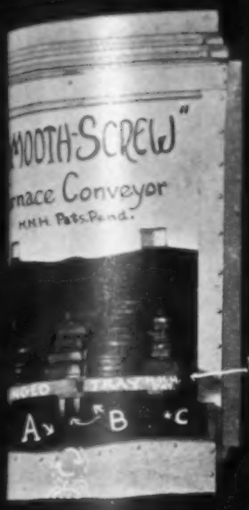
THE high spot of the show came for me early one morning after the customers had put all our salesmen to bed. Neil Phillips, Henry Heyn, George McCormick and I had forgotten about furnaces, alloys and chores of the day. Leaving the tread mill behind, we sought the answer to that question so unfathomable alike to philosophers and European money-grubbers: "What drives vital Americans to work so tirelessly." The answer, satisfactory to me, expounded by Neil Phillips as Surface Combustion credo is **"Loyalty to the vision of work well done."**

THE thought returns me to an evening in Newport, drinking Port that came over on Endeavor II by candle light in quaint Muenchinger-King. A Famous British writer was listing the components of his ideal life. "The insatiable love of a beautiful woman. Supreme contempt for achievement. The quest of a not quite attainable ideal."

"BOARD-WALK," millions of heels, grinding wood from a ten-mile-timber-strip into the eternal sands, pound the questions: "Why Atlantic City"—"Whose fault"—"To get even with who." It is probably most justifiable because it takes so many objectionables out of New York. Here you meet the new aristocracy, the lesser political lice, and the C.I.O., where people go to be seen seeing the ocean. "The sidewalks of New York" in "Joisey," just a dreg drag. The probability of your getting better alloy castings will be measurably increased when you issue instructions to send all inquiries to General Alloys.

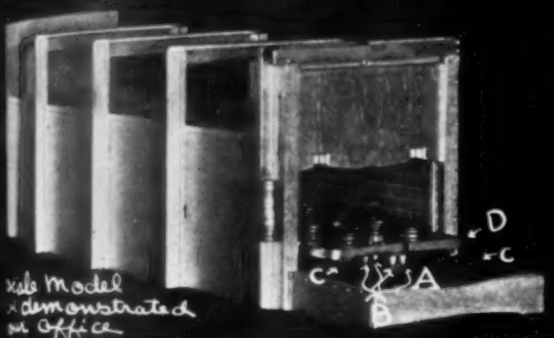
IT is reasonable to assume that a Furnace Builder who specifies General Alloys alloy parts isn't chiseling on other parts of the job.

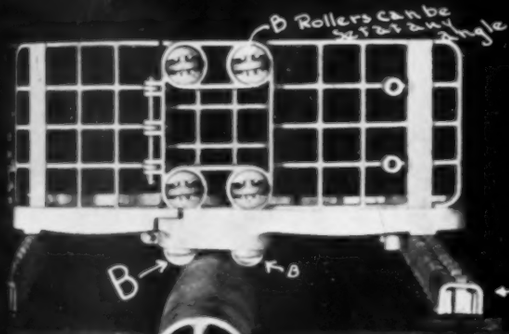
NO FURNACE IS BETTER THAN ITS ALLOY PART

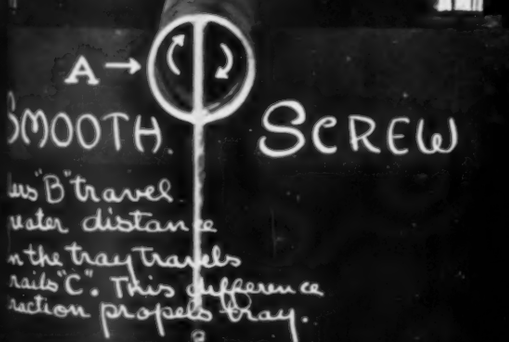


"SMOOTH SCREW"

The simplest high temperature conveyor mechanism obtainable. Hinged trays "D" rest upon two standard roller rails "C" and center tubular "Smooth Screw" shaft "A". Rotation of shaft "A" rotates angulated rollers "B" on trays "D" propelling trays thru furnace foward or reverse, singly or in row, with or without spacing as desired, in any speed. No compression on tray, it is lighter than pusher type.

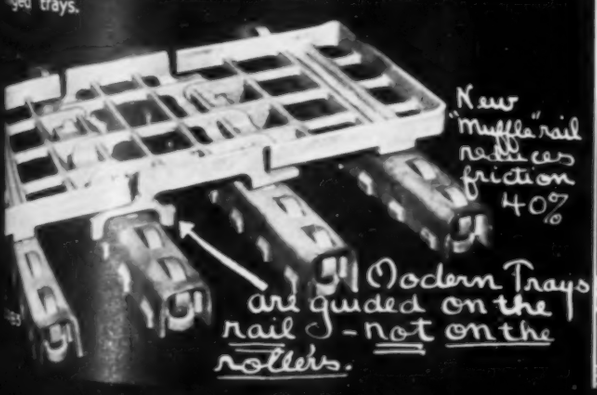






"B" travel
distance
the tray travels
rails "C". This difference
action propels tray.

mize your old pusher furnace to save 40 percent in
eight and get 30 percent increased life with multiple
nged trays.



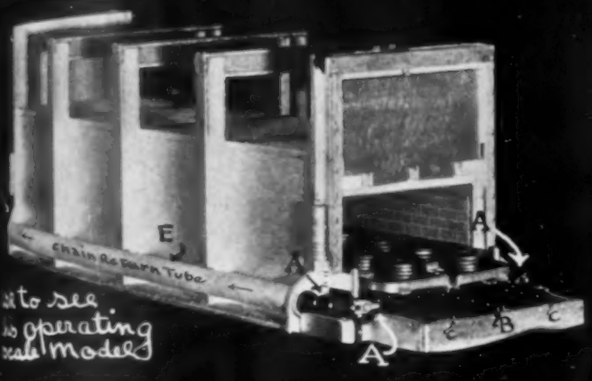
American Society for Metals
SPIRALI
CONVEYOR FURNACE HE
RADICALLY NEW • STRONGER • BETTER •
"SPIRALINK"
CONVEYOR HEARTH
Engineered Alloys
METALLURGICALLY-MECHANICALLY
THE FOOTSTEPS OF GENERAL ALLOYS MARK THE PATH OF AN INDUSTR
GA X-ITE
GA O'ALLOYS

NEW TYPE
Of Simplified Roller Chain Conveyor Mechanism

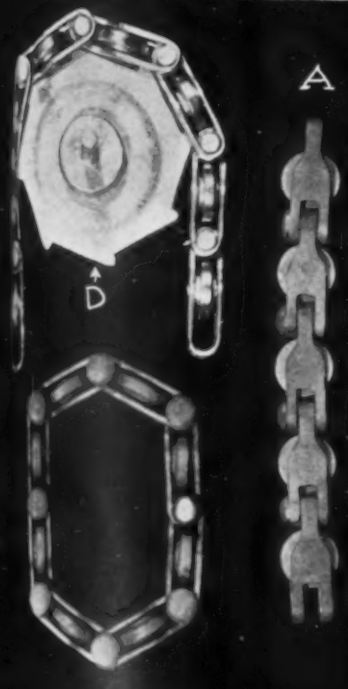
Use of Hinged Trays makes this highly efficient design possible.

Makes large savings in first cost and tray maintenance.

Roller "Vertizontal" chains have horizontal roller pins and vertical hinge pins. They turn on sprockets "D" and return, forming endless belts thru insulated return tubes "E". Chains run in channel rails. Load is carried directly on chains "A" and center roller rail "B". Rails "C" are outside furnace for loading and discharge only.



to see
operating
scale models

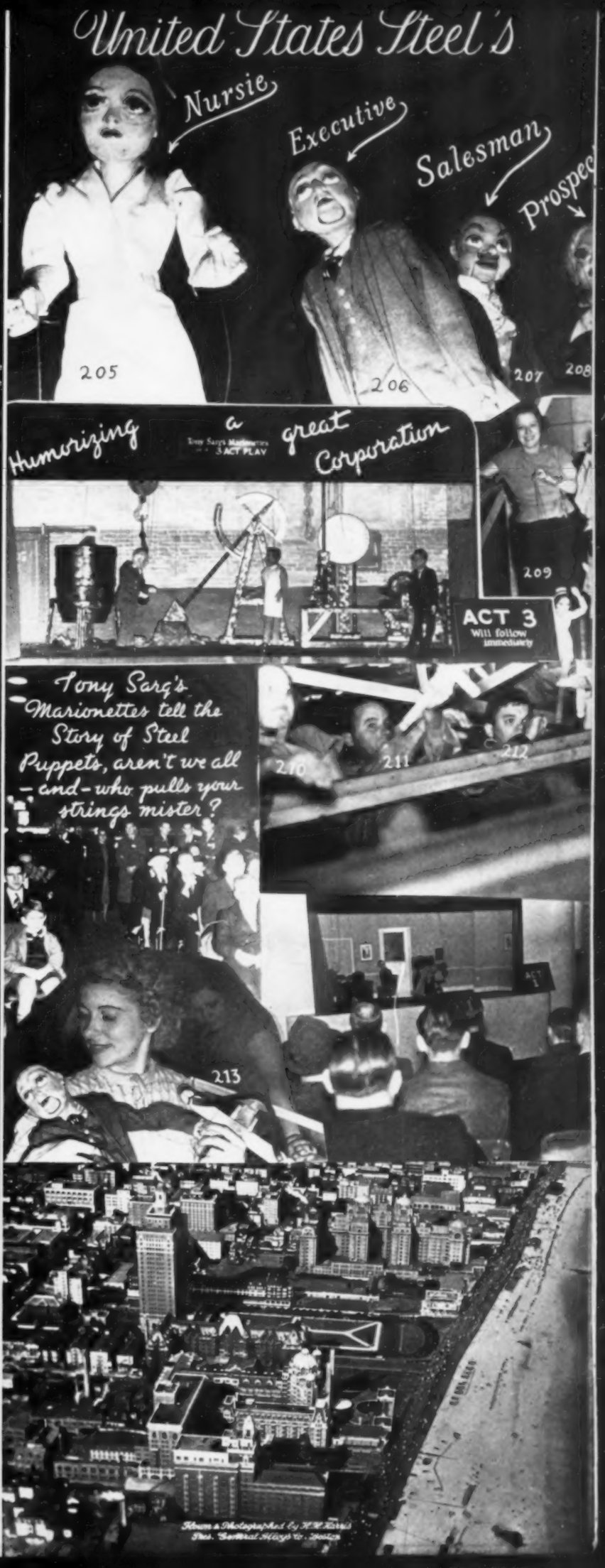


ADVANTAGES OF "SIDE WINDER"

1. Only two chains required for tray. Width up to 4 ft.
2. Chains return on sides of furnace permitting instant accessibility and eliminating costly tunnels under hearth and largesprocket drums.
3. Chain rolls on return as well as working travel eliminating drag wear.
4. Trays travel at twice chain speed reducing chain travel and heat loss 50 per cent.
5. All rolling friction under load on roll periphery.
6. No compression on trays-big alloy saving on lighter tray.
7. Trays can be run singly or in solid line.
8. Self emptying without "dummy" trays to clear load.
9. A standardized mechanism fully guaranteed.
10. A simpler cheaper job of furnace and mechanism.

NSULT YOUR FURNACE LDER

Side Winder" conveyor mechanism is ade as standard equipment thru lead- nace builders for application to jobs ich it is best suited. "Side Winder" is 30 General Alloys engineering con- ns in alloy manufacture to keep pace he outstanding progress of the furnace er in furnace design, combustion and ved furnace efficiency.

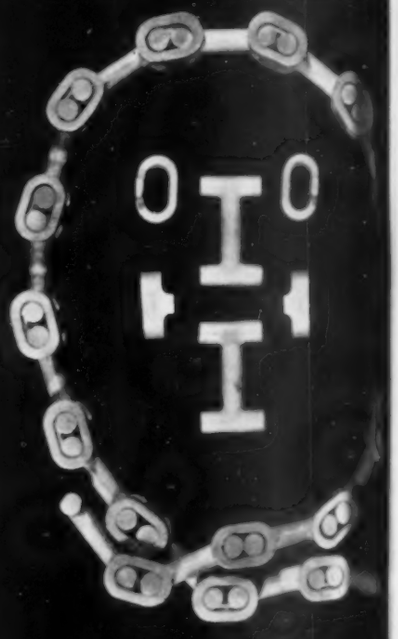


I-O LINK A better Job Chain Engineering

New simple light lin… pitch using small … ket permits retu… inside simple rail … soleting most typ… hearth returning … a better mechanic… lower overall cost. … unequalled alloy … Consult your furn…

"I-O LINK" In-A-Rail Cha…

(M.H.M Pats Pend.)



IN - A - RAIL CHAIN

The I — O Link is mechanically the simplest and most logical chain ever made. It is made from two interchangeable parts welded in place (separable connecting links are provided).

Roller bearing sprocket shown is 7 1/2 pitch line diam. and sprockets as low as 4 in. P. L. D. are recommended. Weight 2 1/4 lbs. per ft. breaking strength cold 10,000 lbs. pitch 2 1/4 in. "Runner" contour of link slides easily and provides large bearing surface. No side projections permits close side clearance in rail or running on end where desired. Double tooth sprocket design insures straight line drive, less wear. Uniform section insures uniform heating and cooling with long fatigue life. "I" section can be thickened to provide flat top or bottom surfaces as required. Various attachments can be easily added. Short pitch greatly reduces sprocket cost, and hot roller bearing sprockets in place of drums can be used where desired. Try to simplify this design.

Hot Q-Alloy Roller Bearing operated up to 140 RPM … 2000 deg. F. Full engineering report available.

GENERAL ALLOYS COMPANY

367-405 W. FIRST ST., BOSTON, MASSACHUSETTS, U. S. A.

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CHAMPAIGN, ILL.

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North Hills, Pittsburgh

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H. G. Chase, Dist. Mgr.
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Alliance

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Hal W. Reynolds
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G. H. Stine
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DAYTON
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RICHMOND, VA.
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S. Craig Alexander
976 Clayton St.

LOS ANGELES
J. Allan Armstrong
100 N. Ridgewood Pl.

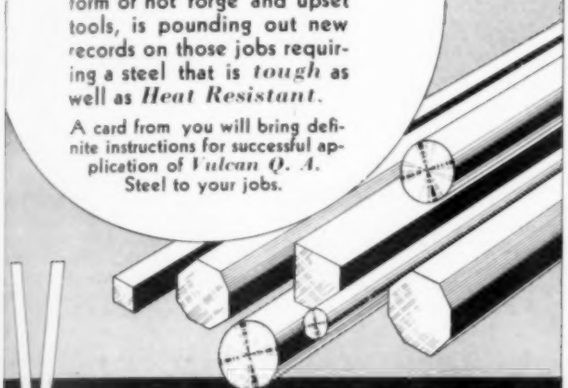
OLDEST AND LARGEST EXCLUSIVE MANUFACTURER OF HEAT & CORROSION RESISTANT ALLOY

FINE TOOL STEELS
FOR EVERY PURPOSE

FIFTEEN SECONDS OF YOUR TIME . . .

to read this ad . . . yet every fifteen seconds of the day *Vulcan Q. A. Steel*, in the form of hot forge and upset tools, is pounding out new records on those jobs requiring a steel that is *tough* as well as *Heat Resistant*.

A card from you will bring definite instructions for successful application of *Vulcan Q. A.* Steel to your jobs.



VULCAN CRUCIBLE STEEL CO.
ALIQUIPPA, PA.
Established 1900

Roots
CONNERSVILLE
ROTARY DISPLACEMENT METERS

The important function of a meter is to give you quickly an accurate record of all gas used in your plant, or in specific departments where you want to break down your costs.

A Connersville meter does just this. There are no delicate parts to wear or require adjustment. You read a Connersville meter direct in cubic feet from a simple register or from a chart.

Installation is compact and simple. One meter will check all the gas for a large plant, sizes being available with capacities of four thousand to one and one-half million cubic feet per hour. Individual meters for separate departments are reasonably priced.

TOMORROW'S ENGINEERING APPROVED BY YESTERDAY'S EXPERIENCE

ROOTS-CONNERSVILLE
Blower Corporation
CONNERSVILLE, INDIANA

HEROULT *Electric* FURNACES

New type-1½. Floor attached to shell, tilts with furnace.

USE them for efficient melting and refining of all kinds of ferrous materials by either basic or acid process—including alloy, tool and forging steels, iron and steel castings. Any capacity from ½ ton to 100 tons; removable roof, chute, machine or hand charging.

AMERICAN BRIDGE COMPANY
General Offices: Pittsburgh, Pa.
Offices in the larger cities
Columbia Steel Co., San Francisco, *Pacific Coast Distributors*
United States Steel Products Co., New York, *Export Distributors*

UNITED STATES STEEL

Help Yourself

to this

HELPFUL LITERATURE

Newer Tool Steels

Vulcan Crucible Steel Co. has a complete and attractive catalog listing their full line of tool steels including many special types to meet the modern trends in industry. Bulletin Jy-127.

Cu-Ni-Cr

A patented Cu-Ni-Cr steel made by Continental Steel Corp. is known as "Konik." Two folders describe its strength, toughness, corrosion and wear resistance, and its suitability for such applications as tire chains, fencing, ball races. Bulletin La-185.

Pyrasteel

The remarkable performance of "Pyrasteel" and "Evansteel" in parts subjected to intense heat or excessive abrasion and load is exemplified in a bulletin by Chicago Steel Foundry Co. describing castings of these materials for the cement mill industry. Bulletin La-184.

Displacement Meters

In a bulletin on rotary displacement meters the Roots-Connersville Blower Corp. describes not only the general operating principles of the meters, but also gives typical proof curves, illustrations of advanced meter design, and views of installations. Bulletin La-131.

Binocular Mike

Extremely wide field, long working distance, and stereoscopic vision are only a few of the advantages cited by Bausch & Lomb for the improved KW wide field binocular microscope. Price list and description of accessories included. Bulletin La-35.

Ingot Production

"The Ingot Phase of Steel Production" is the title of a book defining the principles of quality ingot production followed by many well-known steel manufacturers. Gathmann Engineering Co. Bulletin Ka-13.

Furnace Line

A distinctive direct mail piece presents for the first time in one publication Leeds & Northrup's unusual line of Vapocarb-Hump and Homo furnaces for hardening, annealing, tempering and nitriding of tools, dies and production parts. Bulletin La-46.

Dies and Tools

A. F. Holden Co. offers a booklet describing their new product, Holden Di-ard, for the heat treatment of die and tool steels. Contains interesting data on quenching media. Bulletin La-55.

P.D.M. Box Furnaces

Standard sizes and specifications for box-type furnaces, oil or gas fired, made by the Philadelphia Drying Machinery Co., are listed in a bulletin which also contains a labeled photographic diagram of the furnace. Bulletin La-150.

Insulbrix

Every high temperature furnace owner should be interested in a bulletin by Quigley Co. on a light weight, porous, cellular, low heat storage insulating firebrick known as Insulbrix. Bulletin La-139.

Vanadium Castings

A new 24-page bulletin well illustrated with more than 20 photographs contains a complete description of the properties and applications of a number of vanadium alloy steels for castings where high strength is required without excessive weight or high cost. Vanadium Corp. of America. Bulletin La-27.

Pipe Lines

Latest information on the construction of pipe lines by electric welding for transportation of oil, gas and water is contained in a bulletin by Lincoln Electric Co. Fourteen pages, profusely illustrated. Bulletin Ia-10.

Pictorial Story

A pictorial and descriptive story of the manufacture of steel products by The Youngstown Sheet and Tube Co. is in reality a textbook of basic steel information contained in a 115-page, leather-covered, pocket size ring binder. Bulletin La-93.

Insulation Products

The 1937-38 edition of the Johns-Manville Industrial Products Catalog is a 64-page book, profusely illustrated, containing a wealth of information and recommendations on high and low temperature insulations for every industrial need. Bulletin La-100.

Carburizer

Modern is the furnace and modern is the catalog which describes it. Hevi Duty Electric Co. has an exceptionally well-written, well-illustrated, and artistically printed booklet on the Hevi Duty carburizer which uses the Carbonol process. Bulletin La-44.

Super Blowpipes

Special features in the design of blowpipes giving them unusually good operating characteristics over a wide range are described in a bulletin by American Gas Furnace Co. Bulletin La-11.

Turbo-Compressors

Spencer Turbine Co. has turbo-compressors in all sizes and types for oil and gas-fired furnaces, ovens and foundry cupolas. Special types for special purposes such as gas-tight and corrosion resisting applications are also described in Bulletin Da-70.

Tool Steel Selector

A wall chart, 30 x 20 in., to be used as a means for selecting the proper type of tool steel is offered by Carpenter Steel Co. to tool steel users in the U.S.A. only. Bulletin Jz-12.

Potentiometer Type

Potentiometer type pyrometers, indicating, recording and controlling, are catalogued in a 48-page booklet by Brown Instrument Co., well printed in three colors. Includes the new Electr-o-Line controllers and the Brown proportioning control system. Bulletin La-3.

Aluminum Paint

A practical manual for those interested in the use of aluminum paint contains 102 pages, numerous illustrations, an index, and a chart of finishes obtainable with Alcoa Albron pigments. Aluminum Co. of America. Bulletin La-54.

High Frequency

The well-known Ajax-Northrup electric furnaces are excellently catalogued in a 22-page book, which covers all sizes and types for laboratory or shop. Includes illustrations, diagrams, tables and charts. Ajax Electrothermic Co. Bulletin Ia-41.

Hard Facing

Step by step instructions for hard facing steel with Haynes Stellite are given in an article published in pamphlet form by The Linde Air Products Co. Bulletin La-63.

Drop Stamping

A brand new forming machine known as the "Cecostamp" is being placed in production by Chambersburg Engineering Co., which successfully copes with the latest advances in sheet metal working technique. Details in Bulletin La-132.

Pyrotrol

A safety device for gas-fired ovens and furnaces has been developed by the Bristol Co. for automatically lighting gas-fired industrial heaters and for protection against explosions as a result of pilot light failure. Known as the Pyrotrol, it is described in Bulletin La-87.

EPI Microscope

The Zeiss EPI microscope for the illumination and observation of opaque material has unlimited applications for observing opaque material in dark field, bright field, and polarized light. A descriptive leaflet is published by Carl Zeiss, Inc. Bulletin Aa-28.

Thermit Welding

Of interest to all who are concerned with welding, but of particular interest to students is a pamphlet of carefully explained and illustrated laboratory experiments in Thermit welding published by Metal & Thermit Corp. Bulletin Ca-64.

Defi Rust

Analysis and descriptive notes of nine types of heat and corrosion resisting steels made by Rustless Iron and Steel Co. are contained in a handsome folder. Bulletin Ha-163.

Metal Cleaner

Chemically perfect metal cleansing prior to finishing largely accounts for the marked superiority of metal finishes today, according to E. F. Houghton Co. in a bulletin announcing No. 180 as an addition to its Houghto-Clean 100 Series of metal and maintenance cleaners. Bulletin La-38.

Chapmanizing

Chapmanizing, the new method of surface hardening steel with nitrogen, is described in a very attractive booklet of Chapman Valve Mfg. Co. Information is given out on the method itself and on its metallurgical advantages. Bulletin Ob-80.

Welding Stainless

A new 20-page booklet published by Republic Steel Corp. describes and illustrates the proper methods for welding stainless steel by electric arc, gas, seam, spot, projection, atomic hydrogen, and brazing and silver soldering. Bulletin Ka-8.

Improved Castings

The improvement of plain cast iron, nickel cast iron, nickel-chromium cast iron and nickel-chromium-molybdenum cast iron is technically presented in a 15-page article accompanied by tables, charts and illustrations. International Nickel Co. Bulletin Ka-45.

High Tensile

The 19 advantages that USS Cor-Ten steel offers to railroads and other industries are attractively presented in a 68-page book on this new low cost, high tensile steel published by United States Steel Corp. Bulletin Ka-79.

Stainless Data Book

All users of stainless and heat resisting alloys should find invaluable the information contained in a booklet published by Maurath, Inc., giving complete analyses of the alloys produced by the different manufacturers, along with the proper electrodes for welding each of them. Bulletin Jy-125.

Cleaning Processes

An attractive 12-page booklet entitled "Scientific Metal Cleaning" has been published by Detroit Rex Products Co. It describes in detail the applications and advantages of Detrex degreasing with Perm-A-Clor or Triad Safety Solvents and the applications of Triad Alkali Cleaning Compounds and Strippers. Bulletin Oy-111.

Heating of Metals

A strikingly printed and illustrated booklet by Surface Combustion Corp. traces the applications of heat from the ingot soaking pit to the last phases in which heat is applied to metal, and interestingly describes Surface Combustion equipment for all of these operations. Bulletin La-51.

Some of the Best Thinking

in the metal industries is at your disposal in the literature described here. One booklet may hold the key to your current problem. Help yourself to this helpful literature. It's free. You incur no obligation when you return the coupon.

Cleaning Rooms

A catalog of designs for blast cleaning rooms incorporating many labor and time saving improvements making the blast room an unequalled mechanical device for low cost cleaning is published by Pangborn Corporation. Bulletin Ca-88.

Mo-W High Speed

J. V. Emmons, metallurgist for Cleveland Twist Drill Co. and largely responsible for the development of the molybdenum-tungsten high speed steels known as Mo-Max, has prepared a general description of these new steels. Bulletin Ka-103.

Pyrometer Variety

An eight-page booklet by Wheelco Instruments Co. describes 13 types of indicating pyrometers and combination pyrometers and switches ranging in size from the small portable type to the large 8-in. scale wall mounted type. Bulletin La-110.

Molybdenum

Climax Molybdenum Co. presents their annual book giving new developments in molybdenum, particularly as an alloy with iron and steel. The engineering data presented are made clear by many tables and illustrations. Bulletin Dc-4.

Photoelectric Balance

C. J. Tagliabue Mfg. Co. has christened its newest, simplest and fastest recording potentiometer the "Cetactray" from the photocell, electric current and light ray by means of which it operates. Described in Bulletin Ea-62.

Stainless Service

Joseph T. Ryerson & Son, Inc. has ten plants handling Allegheny stainless steel and service. A beautiful booklet describing and illustrating in color the products and services available is ready for distribution. Bulletin Jy-106.

Radiation Pyrometer

The Pyro radiation pyrometer for temperatures exceeding 1000° F. is a light-weight, handy, and simple automatic instrument made by Pyrometer Instrument Co. Its features, methods of use, and applications are given in Bulletin Ax-37.

Stiffness Testers

The stiffness test is especially valuable on materials in the form of thin sheet, strip, rod, and wire which are difficult to test by the usual tension, hardness and ductility methods. A new line of stiffness testers is described by Tinius Olsen Testing Machine Co. along with complete instructions for making test. Bulletin La-147.

Recuperators

Results obtained with Carborundum Company's recuperators using Carbofrax tubes are fuel savings, closer temperature control, faster heating, and improved furnace atmosphere. Complete engineering data are given in Bulletin Fx-57.

Air Weight Control

An illustrated booklet of sure-fire interest to the foundry trade has been issued by The Foxboro Co., explaining in detail the advantages of the "air weight controller" which is in use at many of America's leading foundries, named in the publication. Bulletin Ea-21.

Furnace Parts

A valuable feature of Driver-Harris Co.'s folder on Nichrome cast furnace parts is a table giving the tensile strength of Nichrome castings at various temperatures. Bulletin Da-19.

Chromel

A new catalog has been issued by Hoskins Mfg. Co. covering Hoskins electric furnaces and Chromel elements, which provide uniform heat and automatic temperature control with excellent production and quality of work. Bulletin Ia-24.

Tempering

Vertical batch type tempering furnaces are described in a folder by Industrial Heating Equipment Co. Capacity and production figures and a diagram of the furnace are included along with a complete description. Bulletin Ia-168.

Hansen Control

A simple yet effective method of regulating the electrical output of the welding generator is an important factor in realizing the ideal welding arc. How the Hansen Smootharc single current control does this is described briefly but clearly by F. J. Hirner of Harnischfeger Corp. Bulletin La-171.

Model "Y"

The Sentry Model "Y" electric furnace, using the Sentry Diamond Block method of heat treatment provides exceptional quality high speed steel hardening at minimum production cost. The furnace is described in Bulletin Oy-114.

Centrifugal Castings

Centrifugal casting of stainless, heat and corrosion resisting alloys eliminates impurities and cooling strains and permits thinner and more uniform walls than any other method. This is explained in a bulletin by Michigan Steel Casting Co. Bulletin Nx-84.

Heat Resisting Alloys

Authoritative information on alloy castings, especially the chromium-nickel and straight chromium alloys manufactured by General Alloys Co. to resist corrosion and high temperatures, is contained in Bulletin D-17.

Rockwell Tester

A revised and completely up-to-date catalog on the well-known Rockwell hardness tester is well illustrated and contains 24 pages. Published by Wilson Mechanical Instrument Co., Inc. Bulletin Ca-22.

Metallograph

Leitz Large Micro-Metallograph "MM-1" — most interesting 36-page publication containing numerous photomicrographs on the very latest developments in metallographic equipment. Special attention is given to darkfield illumination. Bulletin Ha-47.

Alloy Castings

Michiana Products Corp. has published a new book describing Michiana corrosion resistant and stainless steel alloys. Generously illustrated, it suggests many savings for the use of these alloys. Bulletin Oy-81.

Cutting Oils

The problems of machine tool lubrication engendered by the high speed production and close tolerances of modern industrial operations are discussed and progress in cutting oils during the past few years reviewed in a booklet by D. A. Stuart & Co. Bulletin Jy-118.

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STEEL CASTINGS

(Continued from page 674)

siderable number of round inclusions of two easily distinguishable classes — oxides (or silicates) and sulphides. Small amounts of appropriate deoxidizers first reduce the size and number of the oxide inclusions; the effect of aluminum, for instance, is to form clusters of very small alumina inclusions. The oxygen-free sulphides then form a low-melting eutectic with the iron and this, being last to solidify, spreads out in thin films or chains of particles at the grain boundaries. This causes the loss in ductility. Considerably more aluminum will form sulphide mixtures of lower solubility, precipitating at about the same concentration as the mixed iron-manganese sulphides without aluminum, and reappear in the solid casting as sizable particles, relatively innocuous as far as embrittlement is concerned.

Discussion with foundrymen present indicated that basic steel, even though containing an equal amount of sulphur, was not embrittled by aluminum to anywhere near the same extent as acid steel. Likewise erratic results are likely if the aluminum is added to the hand shank rather than the bull ladle or furnace (just before tapping). Higher carbon steels seem also more susceptible to the deleterious aluminum effect.

It would appear, therefore, that the control of porosity in steel castings is not just a question of adding aluminum. Like grain size control in steel ingots, uniformly satisfactory results require correct melting and refining routines. The question then remains — "Would not correct melting and molding practice give sound castings, free of porosity and blowholes, *without* the addition of unusually potent deoxidizers?"

POWDER METALLURGY

tungsten & other refractory metals

By Samuel L. Hoyt
Director of Metallurgical Research
A. O. Smith Corporation
Milwaukee, Wis.

THE metallurgical arts utilize several processes for producing metals in finished form, most of which are of early origin. The first of these was the simple hand forming of native or meteoric metals — though it was not long, as history goes, before it was found that metals could be reduced by fire from their ores. That art is still practiced today in the production of Swedish wrought iron. It was also found in early historical times that metals could be melted, alloyed, and cast into shapes.

Later work has developed metallurgy in truly heroic fashion, the most important art being that of smelting and refining by which metal is produced from ore. This includes the processes of the smelter and blast furnace, the converters, the reverberatory, openhearth and electric furnaces. Such are its advantages, both technical and economic, that it is the outstanding metal art. By its means nearly all of the metal of commerce is produced today, though in more recent years electrolytic refining has also come to play an important role.

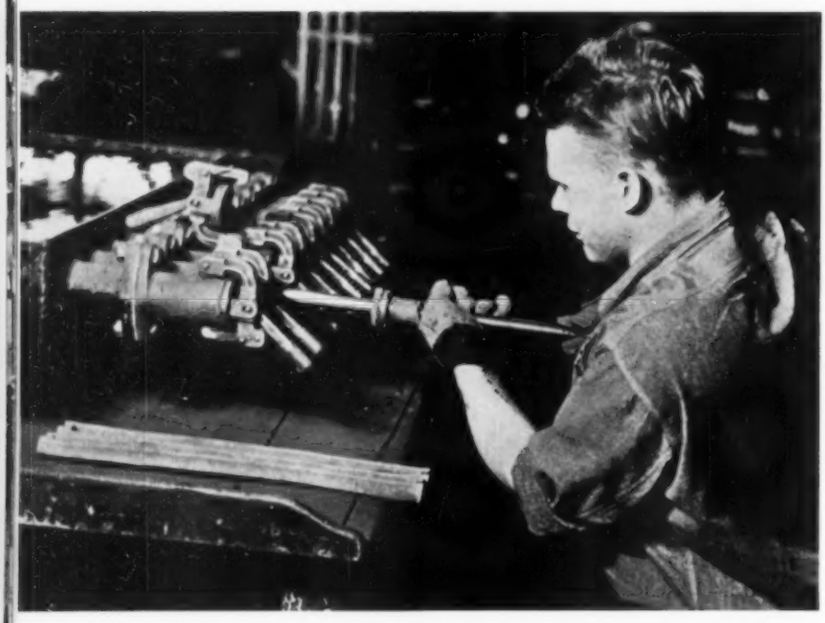
So useful and general are these methods that it is perhaps surprising that a new art, like powder metallurgy, could be developed whose attributes fit it for a competitive position. Such a new art might be expected to have an economic advantage of doing the same thing more cheaply, but in this case survival depends on the ability to do something new.

If I were to attempt to show in detail the position occupied by powder metallurgy and to indicate the reasons for its existence, I should be obliged to devote more time to this phase of the subject than our present interest would warrant. However, while powder metallurgy is not an important competitor of the older arts from the standpoint of the dollar value of the products, it does have unique advantages which fit it for an important and interesting role in science and industry. The older art is used for steel, cast iron, alloy steels, heavy and light nonferrous metals, white metals and precious metals, while powder metallurgy is used for such products as the tungsten and molybdenum of lamps, X-ray and vacuum tubes, the tantalum of the chemical industries and vacuum tubes, and those real modern metal ceramics like the cemented carbides and oil-less bearings.

Before proceeding further we may define powder metallurgy as "that branch of metallurgy which deals with the processing of a metal powder into finished or semi-finished form by thermal and mechanical manipulations at subfusion temperatures." By implication, at least,

we exclude the metal powders which are used principally for the metal paints.

It can hardly be said of powder metallurgy that it was invented or even that it just grew. Rather, it evolved gradually as the only practical way to convert some of the more refractory metals into a usable condition. Perhaps the first use of the art was the Wollaston process for platinum, but it was work on metal filament lamps that made the development of powder metallurgy necessary. The melting points of metals for filaments were necessarily high, and



Chemically Prepared Oxide in a Nickel Boat Is Pushed Through a Tube Furnace, Where a Hydrogen Atmosphere and Accurate Temperature Cycle Reduce It to Metal of Proper Grain Size

were actually so high as to be out of the reach of the ordinary melting and casting practice.

The first metal filament was the osmium filament of about 1900. Osmium metal was prepared as a fine powder, mixed with a sugar syrup, and squirted through a die to produce a fine thread. This thread was heated in a protective atmosphere to carburize the binder and make the filament into an electric conductor. Upon heating the filament electrically in moist hydrogen the carbon was burnt off and the metal particles were sintered together. The details of this process did not become broadly known until 1910 on the issuance of the patent.

A few years later the metal tantalum was used for the same purpose, and this metal, when purified sufficiently by a special vacuum treatment, had the advantage of being ductile. In addition it was plentiful in nature whereas osmium is quite scarce. The tantalum lamp was an excellent one but it was destined to play but a fleeting role in lamp history. This was due to the introduction of superior tungsten filaments, the first of which was prepared from the powdered metal much like the earlier osmium filaments. Tungsten has such a low vapor pressure that it can be operated as a filament at extremely high temperatures to give a lamp of high operating efficiency and long life.

This high quality focused attention on tungsten and the work which was done on it in the early years of this century led to the development of powder metallurgy as we know it. We may well turn to this interesting work as a fitting introduction to this art. Historical phases of the development of the drawn tungsten filament have been covered by me in *Metals and Alloys*, July 1935, page 11, and shall not be reviewed here.

Preparation of Tungsten

Having ascertained that the squirted tungsten filament is an excellent light-source it was next desired to produce the metal in wire form to take advantage of the greater uniformity and superior strength of a wrought metal. This part of the problem was ultimately solved by the development of the fibering treatment by which alone tungsten can be drawn, but for this it was first necessary to make an ingot which could be swaged and drawn to fine sizes. (In this discussion we shall distinguish between the preparation of the ingot and the mechanical treatment of that ingot. The latter is not powder metallurgy though the two phases are so intimately associated that if the ingot is not properly made in all respects, deficiencies in properties or actual defects show up at some later stage.)

The starting material for ingot production is tungsten powder which is made by the reduction of the oxide by hydrogen. As the first step the concentrated ore is either fused with alkali carbonates to produce a sodium tungstate which is dissolved in water and separated from the gangue, or it is treated directly with a hot caustic solution which leaches out the tungsten as sodium tungstate. In either case the tungsten is recovered from solution by precipitation with hydrochloric acid in the form of insoluble tungstic acid. This crude acid is purified by dissolving in ammonia and by subsequent crystallization and precipitation, ultimately to pro-

duce the correct degree of chemical purity for further treatment.

Additions are also made at this time, the two principal ones for filament manufacture being thorium nitrate and sodium-potassium silicate. These additions can be made as aqueous solutions which form a slurry when mixed with the acid crystals, an intimate and uniform mixture which is far superior to any that could conceivably be made in a fusion process. We shall see later what important functions these additions have to perform.

The next step of the process is that of firing the tungstic acid in a refractory crucible at a temperature in the neighborhood of 1100° C. (2000° F.) to convert it to oxide. During this treatment the thorium nitrate is converted into the oxide, thoria, which forms a very fine dispersion, while the time and temperature relations must be such that the correct particle size is produced in the oxide. It may be of some interest to digress here and record the way in which the addition of thoria was developed.

At an early date, when considerable difficulty was being encountered with "offsetting" of the lamp filament when operated on alternating current, it was noted that a certain lot of metal gave filaments which were free from this cause of early burnout. Naturally this lot received considerable attention, for it embodied the solution of an important and vexing problem. It was observed that the metallic grains, instead of being so large that they occupied practically the whole filament cross section, were fine and, what was of especial significance, these filaments remained fine grained throughout life. In such filaments the cross section was filled by many grains so that no grain could slip past its neighbor at the high operating temperature used.

It was finally discovered that this particular lot of acid had been fired in Battersea crucibles from which the charge had taken up a small amount of alumina and silica. Additional work showed that a fine dispersion of such non-metallics acts to restrict grain growth of the filament. Subsequently the addition of thoria as just described was developed as the best means of controlling this grain structure of the filament.

Addition of sodium-potassium silicate was developed in a series of experiments to improve the quality of wire for the coil type of filament which is used in gas-filled lamps. The 218th test was successful and hence the wire acquired the designation "218" at the factory. This addition has just the opposite effect of thoria. When the filament is first heated or "flashed" the grains grow to enormous size with grain boundaries which lie roughly parallel to the length of the wire. This structure is pseudo-single crystal and gives the greatest strength at high temperatures because the effect of intergranular weakness is at a minimum.

This brief outline shows that while the preparation of the oxide is largely chemical, great emphasis is placed on the physical characteristics of the products and additions are made quite early in the process.

Control of Particle Size

The next step is the reduction of tungstic oxide by hydrogen to form tungsten metal powder, the true starting point for the metallurgical operations. The reaction is simple enough and hydrogen has no harmful effects on tungsten, such as a carbonaceous reducing agent might have, but the requirement of maintaining the correct particle size places rather strict limitations on the details of the process. This arises mainly from the coarsening effect of water vapor, the product of the reaction, and the effect of temperature.

For lamp filaments the metal should be relatively fine, though too much fine metal from a low reduction temperature would ruin the quality of the metal. For more massive parts, such as the targets of X-ray tubes, the metal must be made considerably coarser to secure good pressing qualities. Here a higher reduction temperature is used and more water vapor is present in the hydrogen during reduction. For this application the oxide is reduced in a boat which is stationary in the furnace. The hydrogen passes over the charge and as it picks up water vapor, the metal toward the outlet end is coarsened materially. By gaging the dimensions of the charge correctly and by controlling the rate of gas flow, the resulting range of particle sizes can be made correct for the purpose. Metal is produced for the smaller ingots by a continuous process which utilizes a counter current principle of flow of gas against the advancing boat containing the charges.

Various methods are used to judge the metal quality after reduction. Aside from chemical analysis to detect the presence of harmful constituents in excessive amounts, the important test is that for particle size and distribution.

The best way is to spread a sample thinly

on a glass slide, focus the magnified field on the ground glass of a camera extension, classify and count the particles, and then plot size distribution curves, such as those given in a discussion of grain growth during sintering by Smithells, Pitkin and Avery in *Journal* of the Institute of Metals, 1927, II, page 85. The metal reduced at 750° C. (1400° F.) was fine and ranged in size from about $\frac{1}{3}$ μ to $2\frac{1}{3}$ μ (1 μ — 0.001 mm.) with a maximum frequency at about

A Weighed Quantity of Powdered Tungsten Is Carefully Spread in a Steel Mold, Prior to Pressing Into a Coherent Briquette

$\frac{2}{3}$ μ. The metal reduced at 900° C. (1650° F.) varied from $\frac{1}{3}$ μ to $7\frac{1}{3}$ μ with a maximum at $3\frac{2}{3}$ μ. (The values are for the diameter of the particle.) Smithells states that ordinary tungsten powder has a mean particle size of 2 to 3 μ.

Another test of metal quality which has an advantage of great simplicity is the "tap test." For this test a standard weight of powder is tapped to constant volume, which is of the order of 5 g. per cc. for tungsten. Good metal is known to tap down to about a certain density but while this value must depend on a ratio of particle sizes from the finest to the coarsest, it can give no assurance that the range of particle sizes is that desired.

The addition of a test which bears on the absolute location of the distribution shown by the tap test is in a position to add valuable supplementary information. Such a test can be had by observing the way a sample of the powder settles in water. In particular this test shows the presence of too large a proportion of particles of the finer sizes.

Having ascertained the correct way to prepare the oxide and reduce it to metal, the conditions are maintained constant to secure distributions as nearly like those of the desired particle sizes as possible. It is quite likely that no method of mechanical grinding would be able to accomplish this purpose as well.

Having produced tungsten metal powder, the next step is that of pressing the metal into bar or ingot form. This step is entirely different from the analagous step in common metallurgy of casting an ingot from molten metal. While the use of the term "ingot" may imply a body of some size, in the metallurgy of tungsten the size is of the order of $\frac{1}{4}$ in. to 1 in. square as the maximum. The desire is to use as large an ingot as possible, but considerations of pressing quality and quality of the finished product limit the size to this range.

For the manufacture of lamp filaments the smaller size is used; length runs from 6 in. for experimental work to about 30 in. for the production of larger ingots. The mold is a knock-down mold the sides of which are held in place by a side ram during pressing. The powder must be carefully placed in it and distributed uniformly over the length. In all operations the powder must be protected from jarring or other conditions which would produce a segregation of different particle sizes.

With the powder in place the top plunger is inserted and the mold is placed on a hydraulic press. The side plunger is brought home and then the top plunger applies pressure to the powder. After pressing, the mold is carefully taken apart and the pressed ingot is slid off onto a slab. The amount of pressure varies with the metal from a few tons up to 100 tons per sq.in. With tungsten this pressure is about 30 tons per sq.in. At times a binder of some sort is used to secure compact ingots.

If a properly made ingot is broken in two no evidence of corner checks or of pressure cones will appear. If the pressure is applied from only one side, the height is limited to about the width of the ingot — that is, the ingot is made with a square cross section. It is possible to press up circular ingots by putting the powder in a rubber tube and subjecting it to a high hydrostatic pressure. If the rounding up of a

square ingot were more of a problem in converting square ingots into wire, round ingots made in rubber tubes would doubtless be utilized.

In discussions of this operation the question is often raised, "Why is it that the metal particles adhere as well as they do, to form a body that has some strength?" If a binder is used there need be no question, but this tungsten powder is free from any such artificial agents which might stick the particles together. The opinion prevails that the action is simply that two clean metal surfaces will adhere when slightly rubbed or pressed together under sufficient pressure. The correct amounts of coarse, medium, and fine particles provide the necessary areas of such contacts to make the powder adhere in bar form. Possibly the pressure alone is sufficient to produce adhesion, though the sliding action must undoubtedly assist.

The final step in the preparation of the ingot is that of heating it electrically in hydrogen to a temperature just below the fusion point. For this operation the pressed ingot does not have sufficient strength or high enough electrical conductivity and on this account it is first put through a preliminary sintering during which some consolidation takes place. This treatment makes the ingot strong enough to permit handling and to attach contact clips to the ends for the final electric sintering.

Actions During Sintering

The final treating or sintering temperature is determined by heating a pilot ingot according to a predetermined schedule until its center fuses. The actual treating temperature for the remaining ingots of the lot of metal is then taken as about 90 to 95% of the current required for fusion, or about 3000° C. (5400° F.). During this operation the metal is nearly completely consolidated, and becomes a dense, granular ingot with a specific gravity of about 18. This density change is accompanied by a linear shrinkage of about 15%; electrical contact is therefore maintained by dipping the lower clamp in a water cooled mercury well.

This is the true end of powder metallurgy as applied to the manufacture of tungsten wire. The subsequent working of the ingot also differs from common wire drawing practice but those differences are due to the peculiarities of tungsten. Inasmuch as we are here dealing with a step of fundamental significance to both fusion and powder metallurgy — the making of an ingot — we may well compare the two processes in a little greater detail.

Crystallization of a molten mass of metal is commonly considered to occur by the formation of crystal nuclei at the cooler portions of the melt, with subsequent growth of those nuclei into grains. This mechanism, along with certain concomitant phenomena, results in a number of characteristic effects, such as columnar growth, the formation of dendrites, segregation. Crystallization of the tungsten ingot from the initial powder can take place in no such manner and the actual process has given rise to considerable speculation and experimentation.

It is well known that particles of tungsten powder which are initially of the order of 1 μ in diameter are converted into grains which average 15 to 20 μ in diameter. In exceptional cases they unite into grains as large as the whole cross section of the ingot. The process by which this occurs is commonly called grain growth in contrast to the crystallization of an isotropic phase of the common ingot, and the impetus to grain growth is held to come from a strained condition of the particles. These phenomena have been followed in great detail by those engaged in the manufacture of tungsten and reports of these findings have been given by Smithells and his associates in the paper cited, and by Zay Jeffries in *Transactions*, A.I.M.E. for 1919, Vol. 90, p. 588, as well as by German and Dutch writers. At this place we shall consider only the two additions previously mentioned.

Thoria occurs in tungsten as a fine dispersion of particles which are small in comparison to the size of the grains of the treated ingot. It was found by Jeffries that as the amount added increases, the grains of the fully sintered ingot become smaller until about 2% has been added, when the tendency changes and the grains become quite large. At still higher percentages of about 5% the grain becomes fine again. If we hold that the fine dispersion acts somehow as a barrier to grain growth under the usual conditions of heating, it is clear that the barrier is broken down when the critical amount of 2.5 to 3% of thoria is present.

The sodium-potassium silicate addition distills off nearly completely during the treatment of the ingot. This action is purifying to some extent but, according to Jeffries, a small amount of non-metallic residue remains to place a stamp on the recrystallization properties of the metal, truly remarkable in its effects — the ingots may come out with such large grains that

they occupy the whole cross section. Aside from indicating that the metal is of the type that grows large grains very easily this is of no importance at the ingot stage, though we have previously seen that this behavior is very important in the lamp.

Again, the pure, undoped metal behaves quite differently in that the grain structure is never very permanent during heatings, and we can see that the presence of even small amounts of impurities or of other addition agents may combine to produce a wide variety of effects.

Tungsten Briquettes Are Quite Fragile Until Properly Sintered When They Become Hard and Brittle. Sintering is done by passing a heavy electrical current through the rod, thus heating it by resistance. Photographs in this article are through the courtesy of Incandescent Lamp Dept. of General Electric Co., Cleveland Wire Works

Furthermore, it is appreciated that a close relationship exists between the character of the metal, the structure developed by the sintering treatment, and the behavior of the metal in mechanical working. This relates particularly to the liability of cracking in swaging and to excessive die wear in drawing. An interesting discussion of some of these points has been given by Jeffries in his paper above cited.

Before leaving tungsten I shall mention one quite interesting and striking observation of H. Alterthum, *Zeitschrift für physikalische Chemie*, 1924, p. 1. He found that upon heating a tungsten ingot in moist hydrogen for somewhat longer periods than are customary and just below the melting point, the entire ingot is converted into only one or a few grains.

Molybdenum, Tantalum and Columbium

Having discussed tungsten there is no need to discuss molybdenum at such length. The latter has a simpler technology and the requirements placed on it in service are far less severe so that a simplified tungsten practice suffices. Actually molybdenum possesses more "natural" ductility (I do not refer to the ductility of the single crystal) and it was found by Skaupy in 1907 that a sintered molybdenum filament could be drawn cold. This could not be duplicated with tungsten. Pure molybdenum is used for parts of lamps and vacuum tubes, and as the "sealed-in" wire for hard glass seals.

Tantalum, like tungsten, has been known a long time as an element but it was not produced in usable form until it was applied to lamp manufacture. This work showed that properly purified tantalum is ductile and that it has desirable physical and chemical properties — though a special vacuum purification had to be developed to secure those properties. The relatively small amount of work done at that time, just prior to the introduction of the tungsten lamp, did not lead to any important commercial use of the metal. Just after the War a commercial procedure for the production of both tantalum and columbium was formulated.

According to C. W. Balke in *Journal of Industrial and Engineering Chemistry* (1935, p. 1166) this process differs from that described for tungsten. The ore is put through a complex chemical process which isolates the tantalum in the form of purified K_2TaF_7. The metal is recovered from this double fluoride by electrolysis of the fused salt, and is ultimately recovered as tantalum metal powder. This powdered metal is pressed into bars or ingots much like tungsten is. Tantalum reacts when hot with the constituents of the common atmospheres, hydrogen, nitrogen, oxygen, and carbon, and must be heated in a good vacuum for sintering. After the first treatment the bar is hammered and sintered again in the same way. This high temperature vacuum treatment increases the purity of the metal by evaporation of impurities and makes tantalum extremely ductile at room temperature. In this condition tantalum is worked cold into various shapes which go into the chemical industries where the corrosion resistance is utilized.

Preparation of columbium metal is accomplished along similar lines.

MODERN REFRIGERATION

needs modern metallurgy

By William Mikulas
Metallurgist
and L. A. Philipp
Director of Laboratories
Kelvinator Division
Nash-Kelvinator Corp.

REFRIGERATOR equipment presents certain unique metallurgical problems. Many of the materials of construction vary to some extent from those considered standard. Castings, forgings, die castings, stampings and machine parts do not include many factors pertinent to refrigeration. On the other hand, we must prevent corrosion and wear, and seal the compressor units against leaks. These present problems of great importance.

First it might be mentioned that modern refrigeration has been extended to domestic and store refrigerators, air conditioning equipment, coolers for water, milk, ice cream and beverages, and the cooling of automobiles, trucks and railroad cars. In each case, the mechanical equipment includes compressors and condensers for liquefying and cooling the refrigerant, liquid receivers for the latter, and evaporators in which the liquid refrigerant is allowed to absorb heat and evaporate under reduced pressure. Small condensing units in domestic refrigerators are a compact assemblage of compressor, condenser, liquid receiver and motor, and as such are familiar to all readers. Minor parts of the assembly include tubing, valves and regulating devices. Most of the units are driven by electric motors (a few by gasoline engines), and they vary in size from domestic units driven by a ⅛-hp. motor to large commercial jobs requiring 20 hp. For domestic refrigerators the units are placed within insulated, porcelained steel shells, fitted with die-cast, plated and stainless parts.

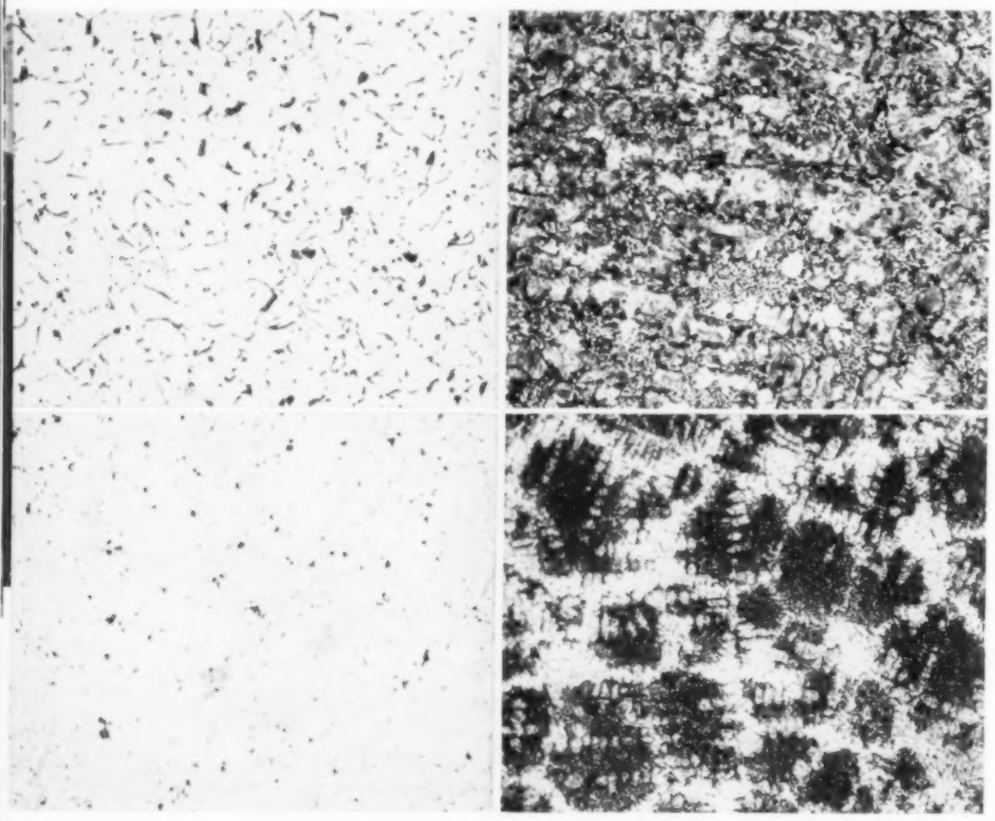
Air conditioning, in addition to a refrigerator for cooling air in summer, requires the use of sheet metal ducts for conveying this conditioned atmosphere from the equipment to the desired outlet. These must resist corrosion over long periods of time. Many of the commercial installations are built specifically for certain conditions; they are installed in stores, office buildings, and moving vehicles, and are subject to varying conditions of corrosion and vibration.

Cast Iron — One of the most important of the metallurgical materials used in the compressor is cast iron for cylinder blocks, valve plates, cylinder heads, pistons, pulleys and some of the connecting rods. A gray iron of the following composition is used for most parts: Total carbon, 3.25 to 3.75%; combined carbon, 0.30 to 0.60%; silicon, 1.70 to 2.70%; manganese, 0.50 to 0.70%; phosphorus, 0.25% max.; sulphur, 0.10% max. The iron for the cylinder blocks, excepting those cast in permanent molds, is ordinarily Meehanite iron, a lower carbon iron with graphite diffused by

calcium silicide in the ladle. Iron castings are checked for hardness and are held to the following Brinell limits: Blocks, connecting rods, valve plates and cylinder heads: 180 to 210; pistons: 160 to 180; pulleys: 140 to 160.

Owing to the Kelvinator design of the cylinder head with an integral intake port, there is some chance of getting a variation in hardness in the cylinder bore. This is objectionable from the standpoint of localized wear and eventual noisy operation. So this matter is controlled by inspection of samples from each shipment of castings. The top two micros illustrate the structure of a suitable cylinder iron. The fine, even distribution of graphite is found in irons Brinelling around 200; a lower hardness is characterized by coarser graphite which breaks out during boring operations, producing a surface referred to as "porous."

Below: Cylinder Iron, Unetched *Below: Cylinder Iron, Etched*



Above: Permanent Mold Iron, Unetched *Above: Heat Treated Alloy Iron, Etched*

Desired Structures (at 100 Diameters) in Cast Iron Parts for Refrigerator Mechanisms

A permanent mold casting is used for the cylinder head of the smaller compressors. Formerly the part had been sand cast and then fitted with a brass service valve, but head and valve body can be cast in one permanent mold. This is a denser iron, much less liable to shrinkage defects. (In the production of cylinder blocks, an unalloyed iron cast in permanent molds yields as dense a casting as a 1% nickel cast iron from sand molds.) Permanent mold castings are all annealed at about 1650° F. to produce a hardness of 170 to 200 Brinell. Machining operations are facilitated because of the absence of any hard skin on the surface. Microstructure is illustrated in the adjoining group.

Iron with the analysis given above, with 0.5% molybdenum added, is being used in experimental crankshafts for domestic compressors. Such an alloy can be heat treated to a hardness of Rockwell C-50. Its ability to withstand wear and to dampen vibrations, along with the economy of production, are important advantages. These crankshafts are cast in a permanent mold around a steel insert which forms the shaft extension for the flywheel, and technique has been developed to the point where a very satisfactory bond is produced between the steel and alloy iron. Torsion tests have indicated an average strength of 3600 in-lb., failure being in the steel shaft every time. Microstructure of the heat treated casting is shown, and at high magnifications appears to be essentially martensitic with excess graphite present. In hardened condition it can be ground and lapped, but machined only with great difficulty. The same iron can be annealed at 700° F. to Rockwell C-40, whereupon it can be machined very readily.

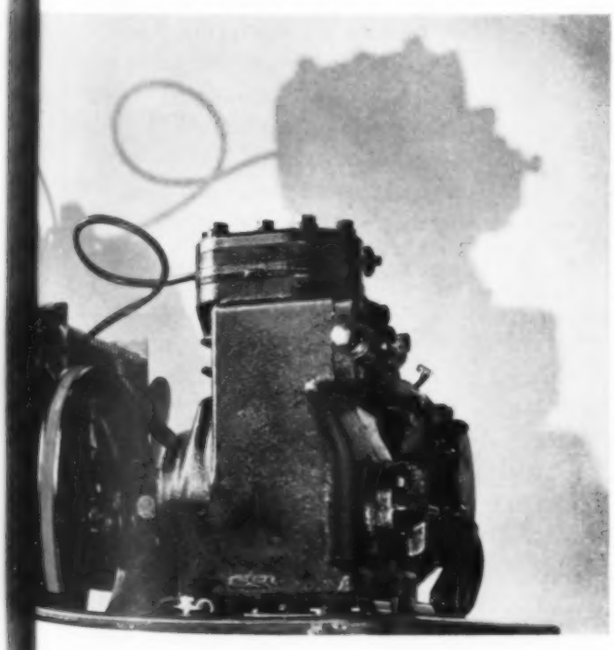
Forgings — The majority of the crankshafts are forged of S.A.E. X-1020 or X-1315 steel. After forging and machining they are carburized to a depth of 0.050 in. and hardened to Rockwell C-62. They are then ground to finish size. The variation from the usual practice in gas engines of using medium carbon alloy steels is due to the considerably lower stresses involved and the greater hardness desired. A relatively heavy crankshaft decreases vibra-

tion in the compressors, and the larger size means lower maximum stress and makes the low alloy manganese steels well suited for the use. S.A.E. X-1315 must be controlled with respect to distribution of manganese sulphide and the presence of external and internal seams. It must also be checked for presence of hard particles of manganese carbide. Since the steel is especially liable to have shallow external seams, our practice is to machine off part of the surface of each test bar before deep etching. Shallow seams either disappear during forging or are removed during machining. Deep seams naturally lead to cracking during heat treatment and are cause for rejection.

The X-1315 steel is used for the smallest crankshafts which require considerable machining, and is therefore specified to be coarse grained. On the larger shafts only the bearing surfaces are machined, and they are made of fine-grained X-1020, although a preferred manganese content of 0.90% is specified in order to attain the desired hardness.

Extreme hardness is required because a shoulder on the crankshaft runs against a leaded bronze bearing and seals the crankcase. One of the Kelvinator crankshafts is shown on page 758 with the seal bellows assembled with bronze bushing up against the steel shoulder. It has been found by experience that the hardest steel surface obtainable is the best resistor of wear and scoring. Faces of both the steel and bronze parts of the seal are lapped before assembly to an optical flatness.

The Heart of the Refrigerator Is Motor, Compressor, Condenser and Receiver



Crankshafts of the largest commercial compressors are made of S.A.E. T-1345 steel, "Tocco" hardened by induction heating to produce bearing surfaces of Rockwell C-60. They are used with forged steel connecting rods. These shafts have shown excellent service; the authors are aware of only one failure, caused, however, by a poorly located flywheel and an absence of oil in the crankcase.

Brass and Bronze — The leaded bronze used in the seal assembly contains 25% lead, 4% tin, and balance copper, supplied by a vendor in the shape of machined rings. Samples are checked for composition and distribution of lead. A typical micro shows effective dispersion of lead globules, with small tendency to form chains or films. These rings are soldered into the seal assembly, the seal face trued up with a diamond tool, and then lapped to an optical flatness on a steel plate impregnated with fine abrasive.

Finishing requires a great deal of care. Considerable damage can be done by diamond tools having dull cutting edges or improper cutting angles. One of the most serious problems is encountered during lapping; particles of lead are pulled out and smeared over the face being smoothed. It seems fairly certain that much of this trouble begins with improper diamond cutting. The use of a dull tool, or one set at an improper angle, will tend to distort the lead particles in the direction of cutting. If this is then followed by a lapping in which some one factor such as speed of rotation, pressure, or distribution of abrasive is not right, the lead pulls out and spreads over the surface of the seal in the form of very small globules which contain some abrasive. This can be corrected only by recutting with the diamond.

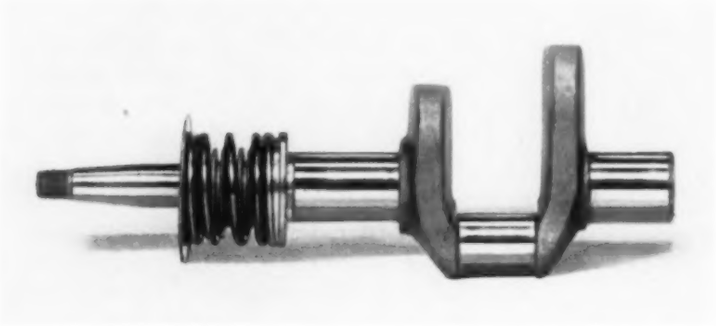
Seals are given a 100% inspection to catch any with a poor surface or large lead particles, and are then tested for optical flatness.

Another important use of leaded bronze is in the casting of small connecting rods. These are used on a small compressor in which the motor shaft and the crankshaft are one, the whole unit being sealed in a shell. The nominal analysis is 76% copper, 10% tin and 14% lead. One is shown in the halftone on page 758; its outstanding feature is that the rod is a simple casting in which the crank and pin openings are bored. The frictional properties of this bronze

provide an ideal bearing surface for the hardened steel crankshaft and piston pin. The tensile strength of these rods averages 3200 lb., which figures to about 29,500 psi. at the point of failure.

Bushings are made of either an S.A.E. 64 phosphor bronze or a 77% Cu, 5% Sn, 18% Pb leaded bronze. Most of the tube fittings are made of S.A.E. 72 leaded brass. Those which are subject to severe service conditions are made of a similar alloy in which the lead is decreased to 1.5% and 1.5% tin added. All these tube fittings are tinplated.

Valve Stock — Compressor valves are of the flapper type and are made of a high carbon Swedish steel analyzing 0.90 to 1.10% carbon (the thinner the strip the higher the carbon), 0.40 to 0.60% manganese, 0.15 to 0.25% silicon, 0.03% sulphur, max., and 0.03% phosphorus, max. The material is received in the form of strip which has been heat treated and ground smooth. It is carefully inspected for any evidence of decarburization, slag, seams, excessive amounts of non-metallic inclusions and non-uniform structure. Tensile strength must be 280,000 to 300,000 psi., depending on the thickness of the strip, with 3% elongation in 2 in. Equivalent Brinell hardness is 480 to 510. Experience with this type of steel has been very satisfactory. Quality of the incoming material is seldom questionable and fatigue failures in the field are rare.



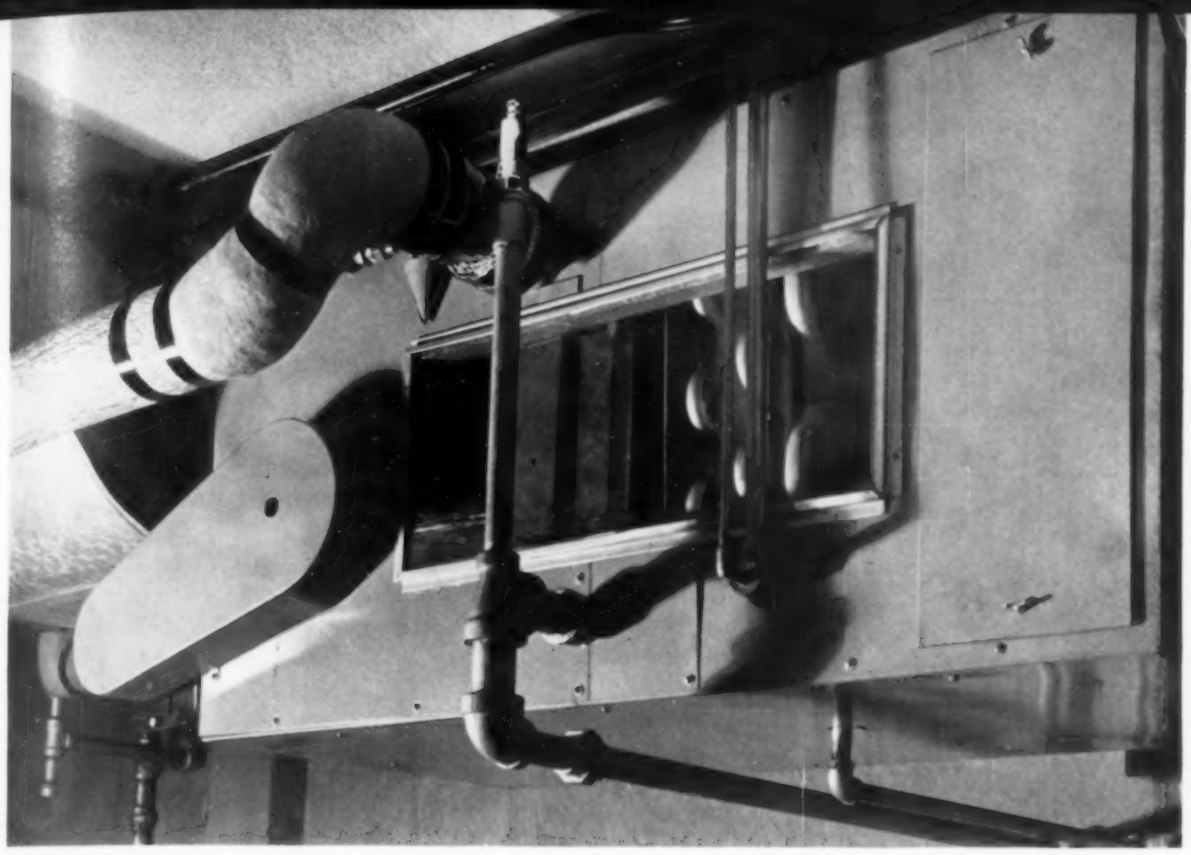
Crankshafts Are Excessively Hard at Shoulder Where They Rub Against Bronze Seal Ring in Bellows Assembly Shown at Left. Mating surfaces are lapped to optical flatness and given 100% inspection

Sheet Metal — A great deal of zinc coated sheet steel is used in the construction of sleeves and compartments of ice cream cabinets, ducts of air conditioning and forced convection heat equipment, sections of water coolers, and several other parts. Conventional galvanized sheet is not used to any great extent because it holds paint poorly; furthermore, other forms of galvanized sheet have better corrosion resistance.

In one type of annealed, zinc covered sheet, manufactured under the name "galvannealed," the zinc spangles are no longer visible; the surface has a dull satin finish which will retain a coat of paint very well and we believe has a greatly improved protecting power. This type of coating has been described in METAL PROGRESS last May by J. L. Schueler. A second form of zinc covered sheet has a surface which has been chemically treated to form a protective phosphate coating. This forms an excellent base for paint because of the crystalline nature of the film; the paint does not come in contact with the zinc. It has better corrosion resistance than a similar galvanized sheet, and compares favorably with the third variety — an alloy base galvannealed sheet. Salt spray tests on these materials are given in the tabulation on the opposite page.

Connecting Rods for Small Motor-Compressor Units Need no Bushings, for They are Made of Leaded Bronze Casting Having Proper Anti-Friction Qualities Against Hardened Piston Pin and Crank

The alloy base galvannealed sheet is the one used to the greatest extent. The base contains about 0.5% copper and 0.15% molybdenum, and is coated with 0.8 oz. of zinc per sq.ft. It can be formed without cracking the coating, and soldering is easy. The chemically treated sheet is being tested further for its corrosion resistance. Tests are also being made to determine the effect of forming operations and soldering upon the protective coating.



With Refrigerating Coils for Summer and Steam Coils for Winter, a Feature of the "Kelvin Home" Is the Air Conditioning Unit

Shells of domestic refrigerators are porcelained or enameled iron. The sheet metal is supplied by several vendors under orders to furnish material suitable for each individual part; attempts to draw up definite specifications have not met with success. Exteriors of ice cream cabinets and water coolers are a low carbon sheet given a Bonderizing treatment before the priming coat of paint. Screw heads used in the trimming are treated to resist rust in the same manner.

Deep drawing stock, used for making float balls, is specified to be hot rolled, pickled, and of a quality suitable for the purpose. Compressor bases, and various brackets and stanchions are punched from hot rolled, pickled strip stock.

Copper sheet is used for evaporator shelves

Hours for Defect to Appear in Salt Spray

Metal	White Spots	Rust Spots
Unpainted		
Galvannealed	24 to 48	48 to 72
Alloy base galvannealed	48	300
Chemically treated	48 to 96	300 to 350
One coat paint		
Galvannealed	72	96
Alloy base galvannealed	100 to 300	700 to 950*
Chemically treated	150 to 350	> 1000†

*No blisters in 1000 hr. †Blistered after 160 hr.

in the domestic refrigerator. The evaporator coils are soldered to the bottom of the shelf and the unit is then electroplated with tin.

Tubing — Annealed copper tubing is used for the liquid and vapor lines connecting the various parts of the refrigerating mechanism, the evaporator coils and for some of the tube-fin condensers. Because of severe bending and flaring in fabrication, the tubing is carefully checked for grain size; a tolerance of from 0.25 to 0.45 mm. is allowed. Tubing must also be clean, bright and dry. The large commercial tube-fin condensers must be rigid, and for this reason a copper covered steel tube is used; the steel imparts the strength required, while the copper layers on the inside and outside of the tube afford the necessary resistance to corrosion.

Solder — Joints in the liquid or vapor lines, where strength is required, are silver soldered, as in joining copper tubing to the liquid receivers and condensers, and making of certain "streamlined" fittings. Copper tubing is fastened to evaporator shelves and ice cream cabinet sleeves with soft solder. The condensers are dipped in a 15-85 solder which provides the bond between tube and fin, and (in the case of the steel finned condenser) protects the steel from corrosion.

It is very essential that no parts on which moisture condenses be soft soldered. Under

such conditions soldered joints will show a peculiar corrosion in which the lead is dissolved, forming probably a basic carbonate, a white deposit following the direction of flow of the water. For this reason, such units as the commercial evaporator (which is a tube-fin type made of copper fins and copper covered steel tubes) are dipped in pure tin. This provides a good bond between tube and fin and does not disintegrate during service. It is interesting to note that the joint produced by pure tin will withstand vibration better than will a soldered joint, and condensers to be installed in gasoline engine units are therefore tin dipped.

Corrosion Resisting Parts — Many fittings are subject to unusually severe corrosive condition due to the condensation of water. The interior of cabinets, all of the various types of evaporators and various brackets and trimmings must be able to withstand such conditions. In the domestic cabinets, most of this is taken care of by porcelaining the liner and the evaporator. Such items as baffles and ice compartment doors are made either of brass stampings heavily plated with nickel and chromium, or aluminum which has been anodized and dipped in a clear lacquer. The wire shelves are chromium plated steel. A bracket which holds the thermostat bulb in position near the evaporator is made of 18-8 stainless steel and must be given a passivating treatment in nitric acid in order to keep from rusting. Bolts which enter the cabinet are cadmium plated steel. Various items used in trimming are made either of 18-8 stainless steel, or are chromium plated parts of steel or brass.

Plating Specifications are drawn up to cover the various service requirements and follow closely those approved by the Master Electroplaters Institute of the United States. Mild service is considered to mean the conditions such as on the outside of the equipment and in the motor compartment where temperatures are fairly even and there is little chance of condensation. Severe service is found in any of the cold parts of the equipment where corrosion is very likely to take place because of dampness. The specifications of plating thickness are listed in the following table:

Type of Plate	Plate Thickness
Cadmium on steel	— 0.0002 to 0.0006 in.
Chromium on brass, bronze and copper	Ni — 0.0003 to 0.0005 in. Cr — 0.00002 in.
Chromium on zinc	Cu — 0.0003 in. Ni — 0.0003 in. Cr — 0.00002 in.
Chromium on steel	Cu — 0.0002 to 0.0004 in. Ni — 0.0003 to 0.0004 in. Cr — 0.00002 in.
Nickel on brass, bronze and copper	— 0.0003 to 0.0005 in.
Nickel on zinc	Cu — 0.0003 in. Ni — 0.0003 in.
Nickel on steel	Cu — 0.0002 to 0.0004 in. Ni — 0.0003 to 0.0004 in.
Zinc on steel	— 0.0002 to 0.0006 in.
Tin on brass and copper	— 0.0004 in.

SCALING OF CHROMIUM-IRON

influence of carbon content

Abstracted from The Metallurgist, *October, 1937*

CONFLICTING statements appear in the literature concerning the influence of carbon on the oxidation resistance of high chromium-iron alloys. Recent work by Oertel and Landt (*Stahl und Eisen*, July 8, 1937) indicates that some of the discrepancies, at least, can be accounted for if allowance be made for the structural phases present in the given alloy at the test temperature. Chromium austenite is intrinsically more resistant to scaling than a conglomerate of ferrite and carbide of the same chemical composition.

Oertel and Landt prepared three series of alloys in a small high frequency furnace; they all carried less than 0.25% of both silicon and manganese. One series contained 10% chromium, another 20% chromium and the third 30%. In each series the carbons ranged from 0.10 to 1.50%. Forged slugs were ground all over, exposed to slowly moving air (or flue gas) in a tube furnace at given temperatures, and the gain in weight figured back to grams per hour per square meter of area. In these tests, generally speaking, *(Turn to page 796)*

The common MACHINE BOLT

A photographic story of its manufacture

by Van Fisher

Made at the Cleveland and Kent (Ohio) Plants of

The Lamson & Sessions Co.

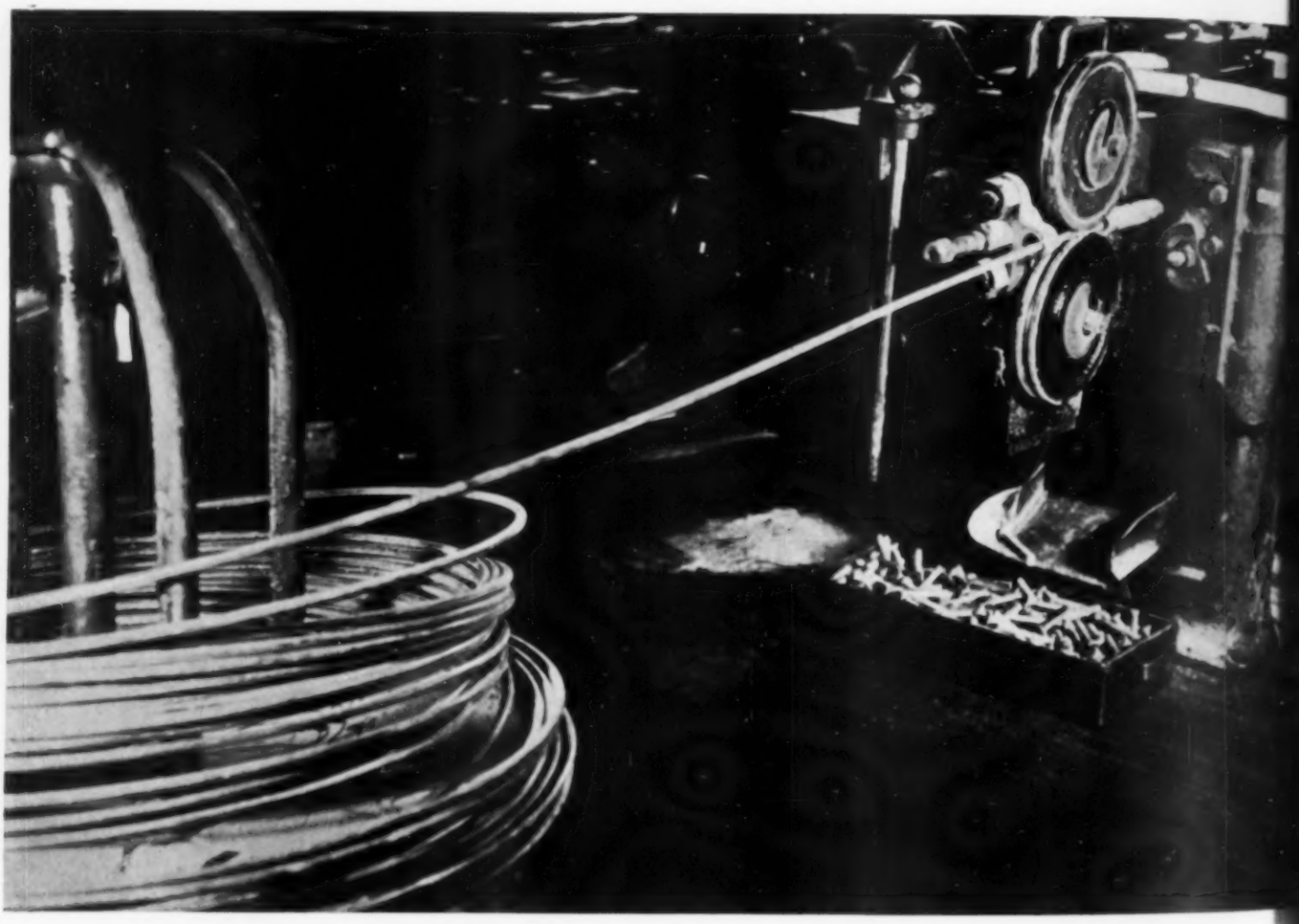
RAW MATERIAL for an industry is hot rolled rods in coils — a staple product of steel mills. Bought to close specifications, its chemical analysis, sound structure, freedom from surface and internal defects are carefully checked on receipt. To insure quick delivery of bolts of almost any size, shape and strength, a generous stock yard is filled, each variety within its own fence.

CLEAN ROD is first drawn through a carboloy die, reducing the diameter 15 to 30% to that desired. Emerging is a rod precise in dimension end to end, coated strong and tight with lime and soap (an invaluable lubricant in later working). Such cold drawing has other advantages beyond a sizing operation, for it strengthens the metal considerably.

ST STAGE in the journey from rod to olt: A bale of coils is pickled free of and mill scale in hot acid, washed in r and neutralized in boiling lime solu- A high pressure hose aids in washing.

The Cold Head

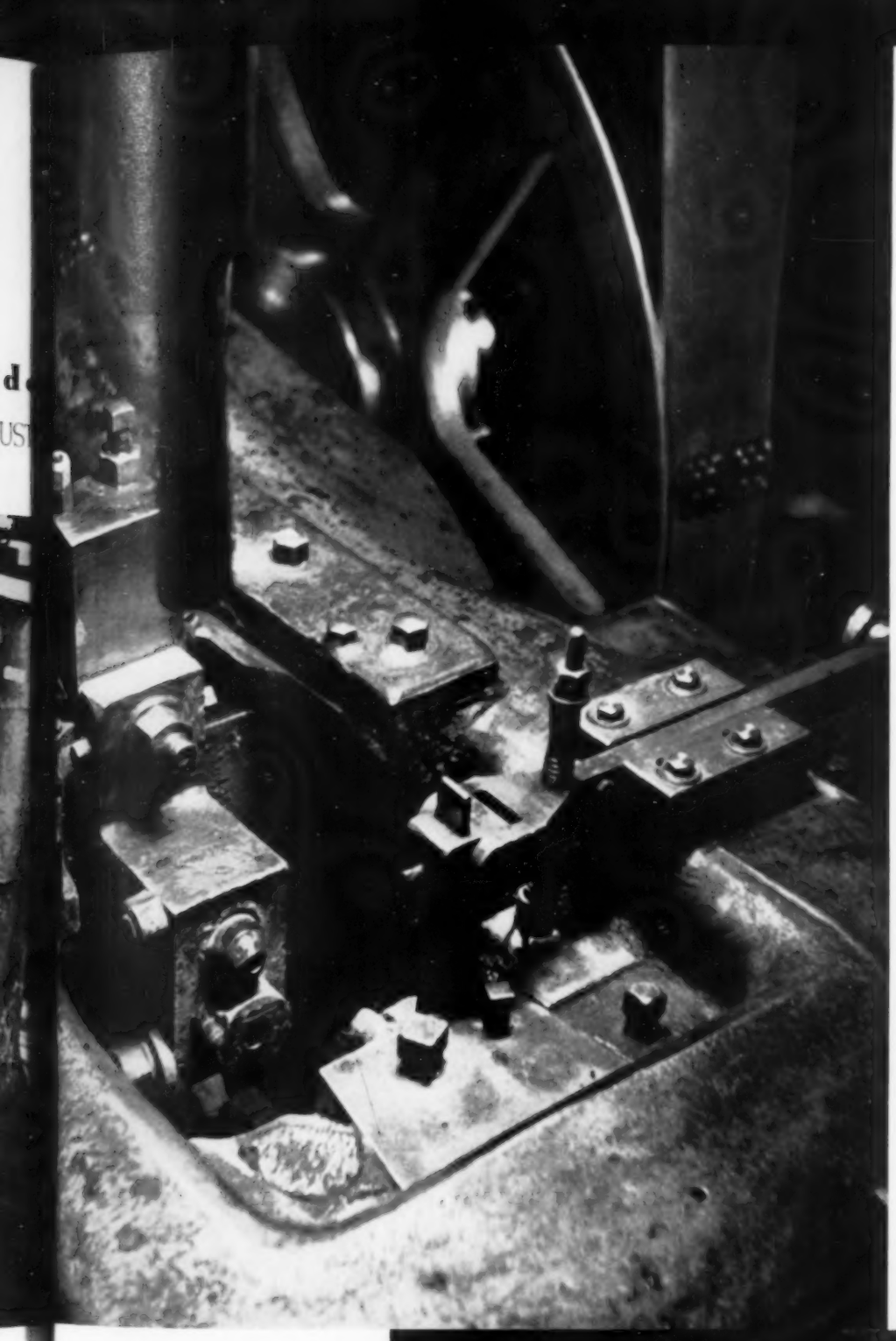
—THE HEART OF AN INDUS



COLD WIRE moves jerkily forward, between feed rolls, into this machine, and, to an orchestration of crunching thumps, out the chute rolls a stream of "blanks" — rudimentary machine bolts.

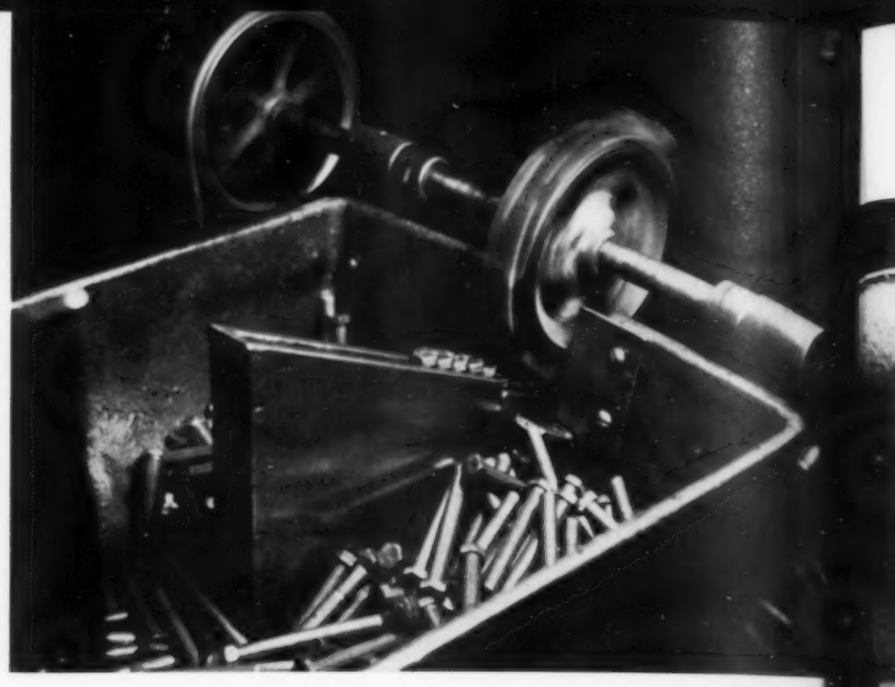
The view above at right attempts to show what hap... meanwhile; it looks down into the header and caugh... motion still, at instant of reversal. Cut-off and header die... concealed behind the strong frame at front. Intermitt... the feeder forces the wire forward against a stop, shear b... cut off a definite length, mechanical fingers grasp the ... and, guided by the ways bolted on top the frame, move it ... ways, stopping immediately in front of the forming die.

One, two or three blows may be required, dependin... the amount of metal upset into the head. In most case... die is stationary in the frame, the reciprocating slide ca... the heading dies or hammers, and these are raised and l... ered in proper sequence so that each strikes the bolt he... turn. In the illustration a two-blow header is shown.



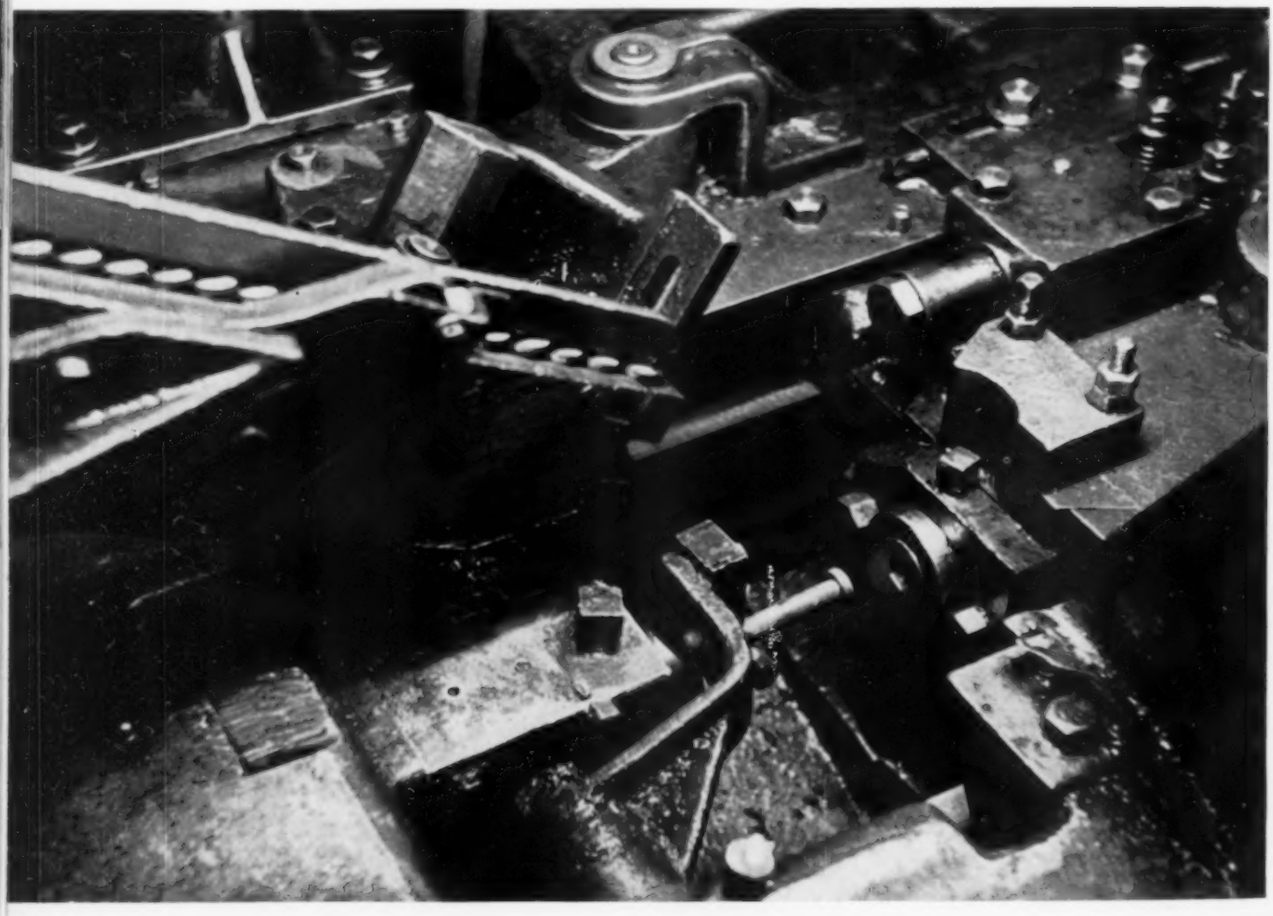
NOTE — Some bolts are headed hot, either because they must be made of a steel variety unsuited for much cold work, because of disproportionate diameter of the head, or because the whole bolt is quite large. Hot heading is frequently done in those forging machines widely used for other types of upsetting. Specialized cold heading equipment also produces certain shapes and sizes of machine bolts in quantity, either to save labor or to increase the accuracy.

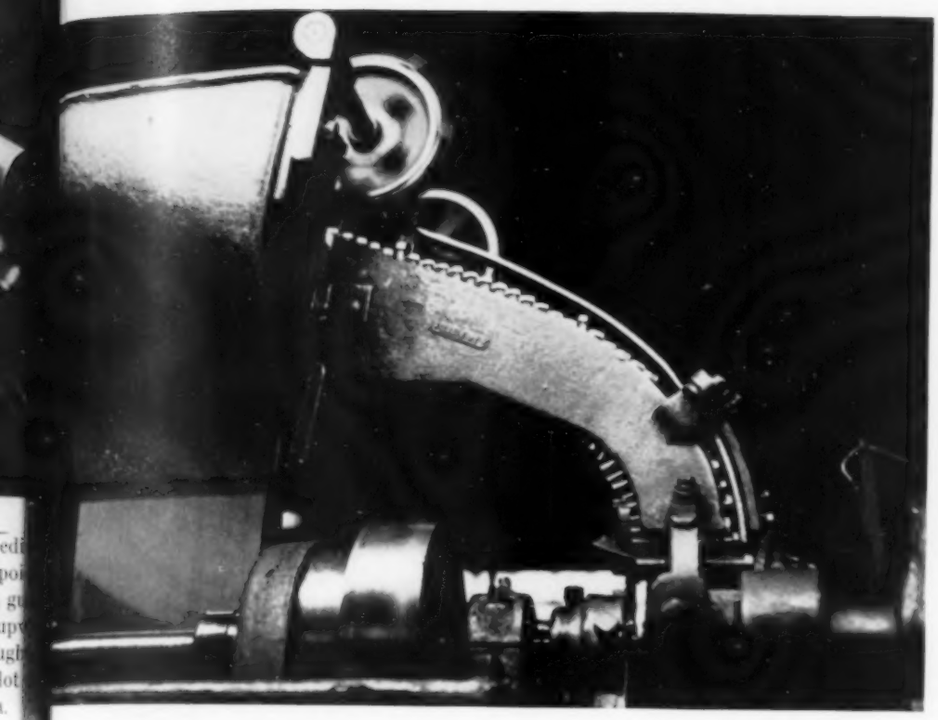
per cone-like heading hammer
hes the sheared blank into the
until it strikes a stop and then
ns a tulip-shaped upset on the
jecting end. The slide draws
k and the hammer heads are
fted upward so the partly upset
nk may be struck by the lower
mmer on the next trip forward of
slide, squeezing the metal snugly
the round cup prepared for it.
kick-out pin knocks the blank out
the die and a new cycle of opera-
ns starts.



BLANKS from the cold header have round heads. In order to obtain a hexagon or square, the head is pushed through the advancing die (a trimming die) and at the same stroke the other end is forced a certain distance into a stationary die to extrude it from nominal to pitch diameter, thus preparing for roll threading. Note a line of blanks sliding down the inclined magazine, and a single one, picked off the end and carried by lever arm down to exact position for trimming.

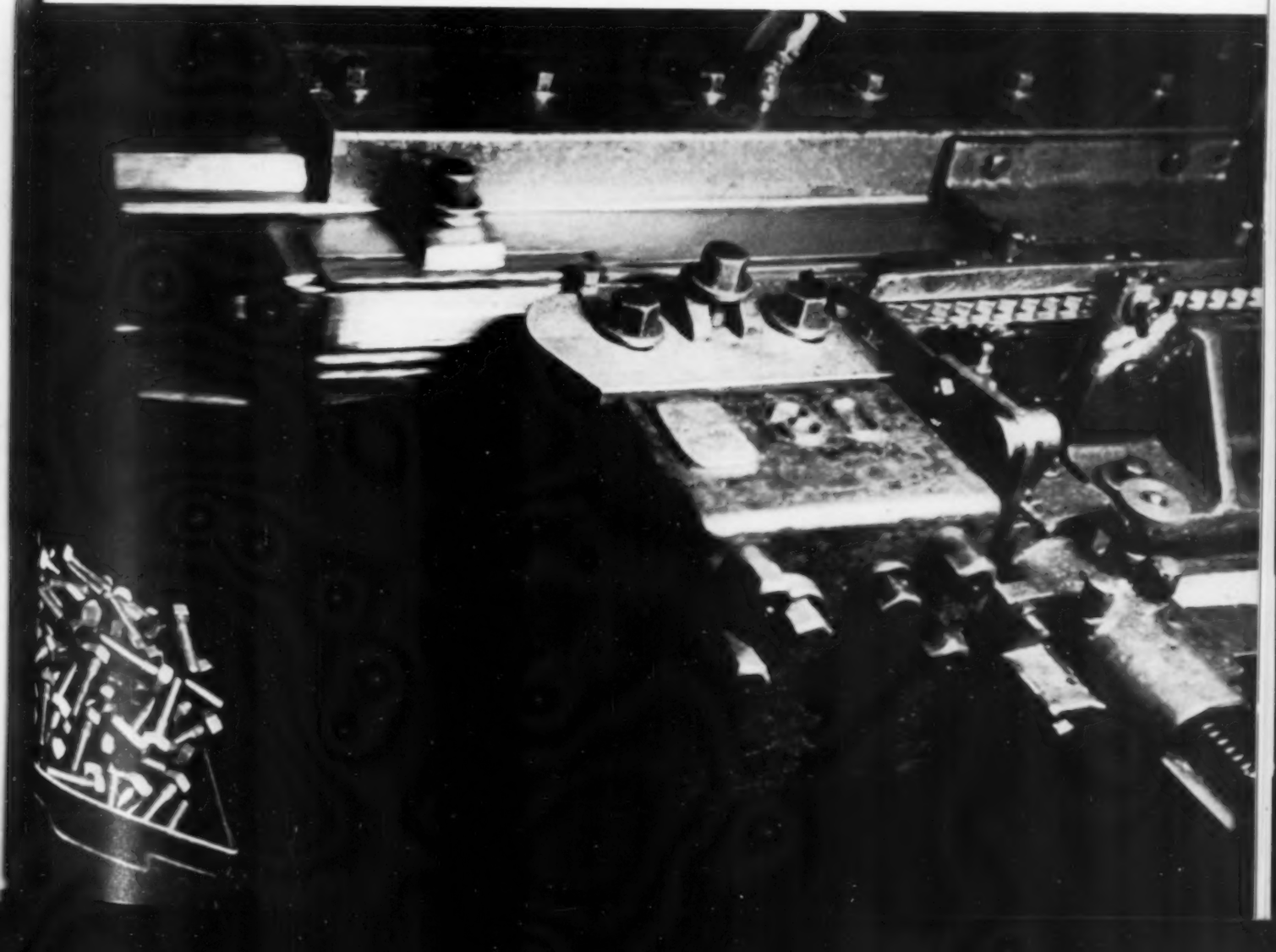
FEEDING DEVICES are exceedi ingenious. In this one the poi slide moves up and down through gu in bottom of the hopper; on each up stroke one or two blanks are caugh the heads ride on edges of the slot the shank dangles down between. hinged wipers on the whirling wheel





e any bolt not properly entering the
ine just below, down which it slips
ol an automatic lathe where the
re-cut end is chamfered or rounded.
operation is known as pointing.

ROLL THREADING is the final mechanical operation. Note, below, a row of bolts, hung from their heads which alone show, advancing from the right. The dies are hardened steel plates, faces ribbed with grooves or corrugations the exact shape of the thread. One die is fixed with three studs on the machine base just ahead of the feeder. The other is on the near face of a massive slide, and on each stroke forward a bolt blank is caught in the slot between them, and the thread is formed on the shank as it is rolled forward, dropping out free and finished at the forward end. Precision tools insure rolled threads of exact contour, smoother than cut threads, and (on account of the cold work) stronger and tougher.



MOST common machine bolts are strong enough if made of plain 0.20% carbon steel, cold drawn. Higher carbon and alloy steel bolts, oil quenched and drawn, give correspondingly higher properties; they must be heated in a non-scaling atmosphere to preserve the thread, precision-cut or -rolled. Other specifications call for casehardening; the bolts and nuts are then heated with carburizing gas for the correct time in a rotating retort, oil quenched and drawn.

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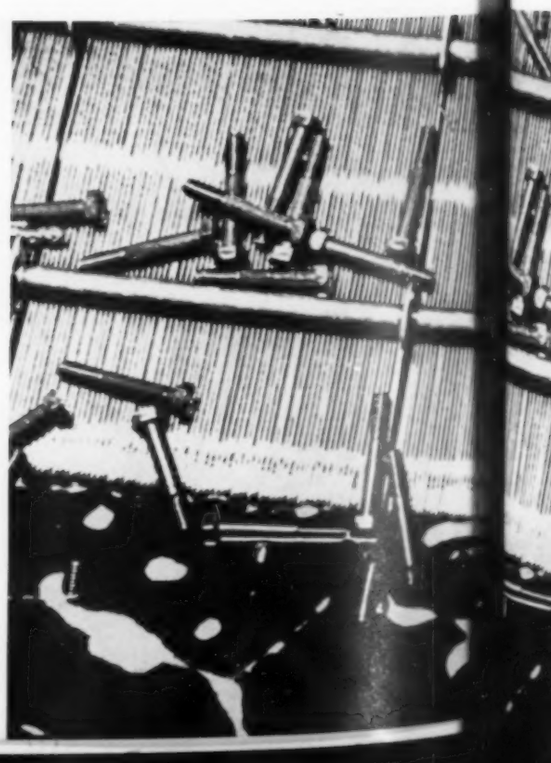
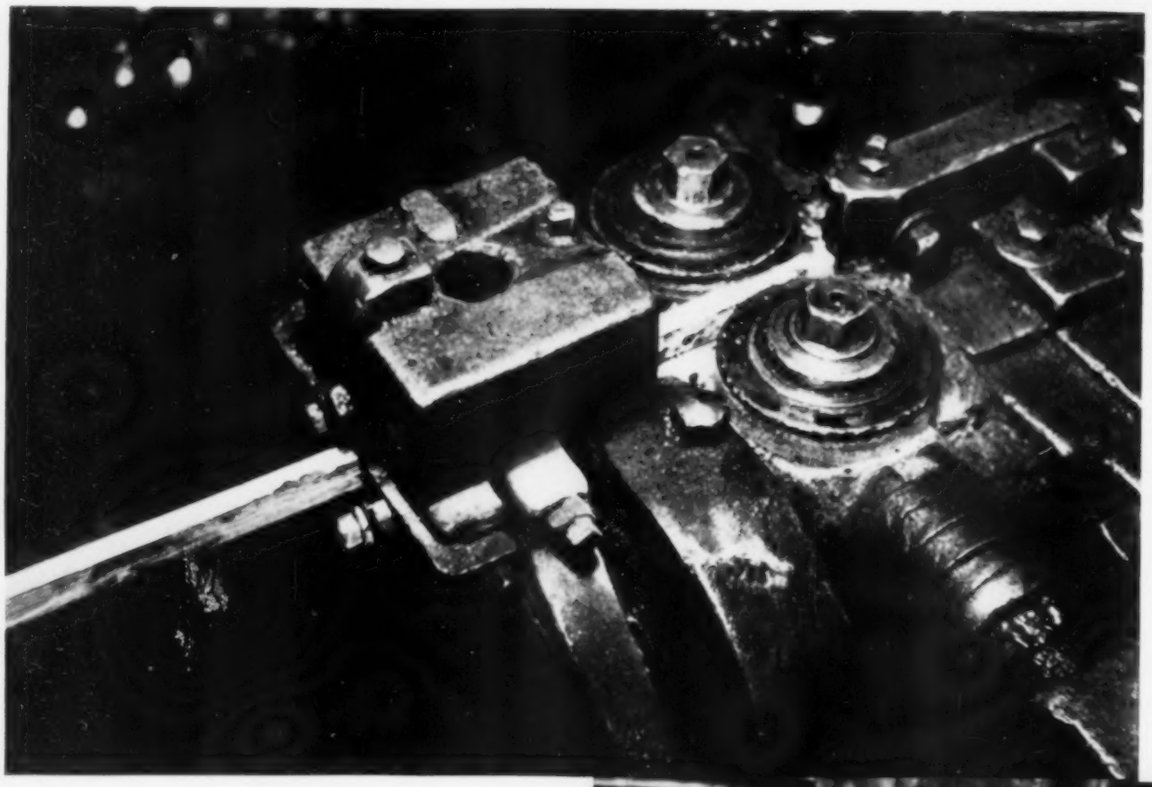


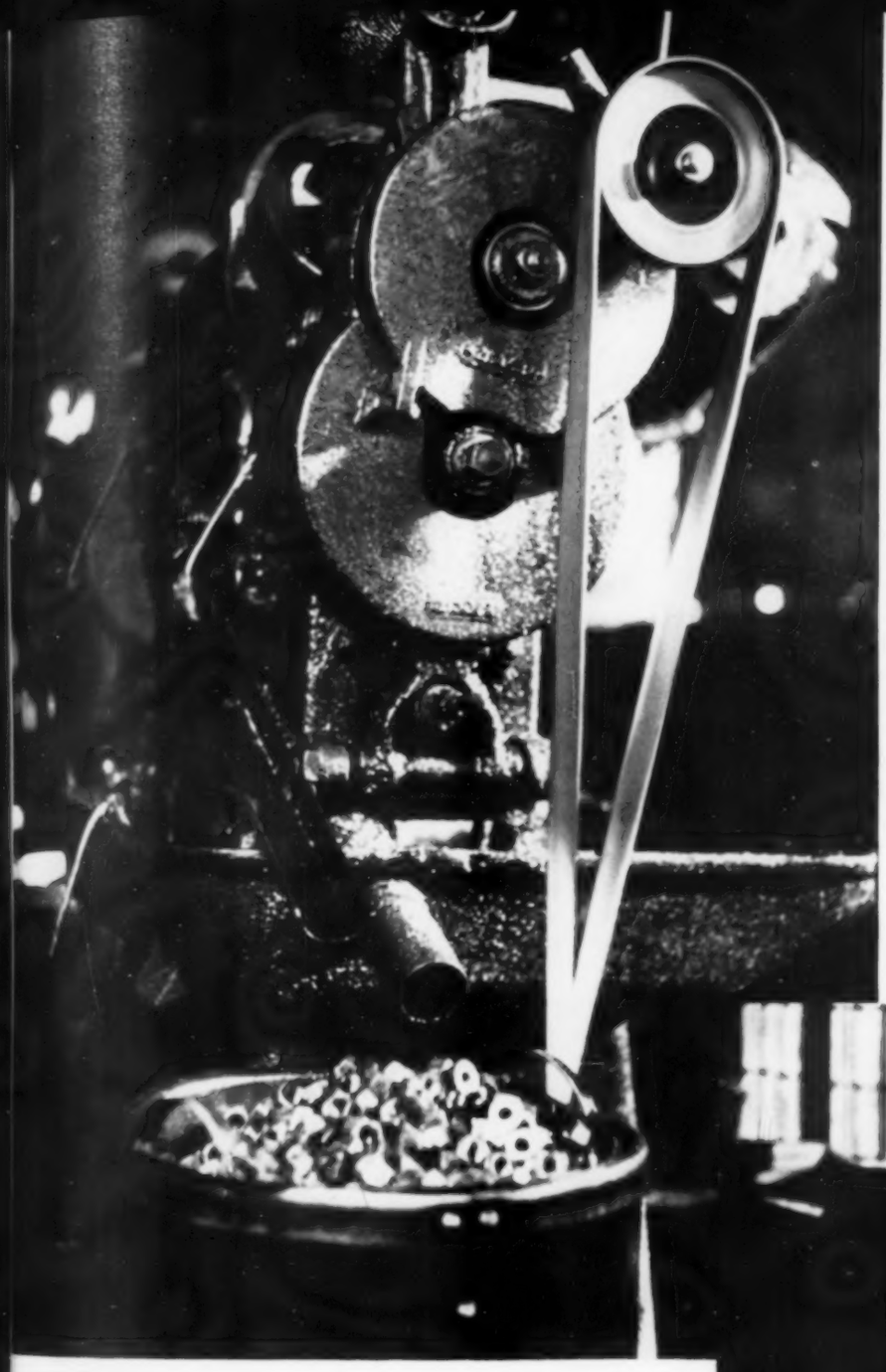
OUT OF THE OIL, up and away to a cleaner, and then to final inspection tables and shipping department. At frequent intervals production of each machine in each step of the process has previously been gaged for accuracy. Hardness and tensile tests on random samples are the rule; special physical tests are made according to specification.



NUT MAKER eats bar stock, and a steady stream of blanks drops out below. Much happens meantime! Much happens before and after!

Hot-rolled rod, pickled and cleaned, is cold rolled into rectangular cross-section in a continuous mill—a succession of rolls set alternately horizontal and vertical. Accurate punches and dies, strong, hard and tough, are made and mounted precisely in the nut maker. Ordinarily three operations are sufficient here; first the center hole is punched, next the crowned top or chamfer is molded, finally the rectangular or hexagonal blank is sheared off. Sometimes the nut is again forced through a trimming die to size more accurately.

When the diameter of thread is large compared with distance across flats it is more economical to use a "scrapless" nut machine, an upsetter which first cuts a slug from a round rod, upsets it to a larger diameter, pierces the hole from top and bottom (but not completely) thus further upsetting the pellet into a hexagonal die.



AUTOMATIC TAPPING machines are entirely encased. Nut blanks are fed one by one in front of a rotating tap. The blank is prevented from turning by suitable jaws, and the thread is cut as the tap bores itself through the center hole..... Inspection is unusually severe at this point. Plug and thread gages, "go" and "no go," determine whether diameters and lead are correct, and optical comparators examine them for contour of thread.

NUTS AND BOLTS are cleaned, barrelled and shipped separately to large consumers. Hardware trade requires assembly and neat packaging. A simple device is all that is necessary — a spinning socket holds the nut long enough to thread it on the bolt.

HIGH FREQUENCY MELTING

By N. Broglio

Abstracted from Report No. 17 to International Foundry Congress, 1936 Meeting in Düsseldorf, Germany

IN THE AUTHOR'S PLANT, the high frequency furnace was installed to replace crucibles for melting toolsteels. It proved to be merely a continuation of the old process in a considerably improved form. The new furnaces were always able to produce steels of at least equal quality; with certain steels an improvement was noted, traced by us to the great ease in controlling the temperatures, or in safely superheating the metal, and in the stirring action of the induced currents.

We rapidly found that the furnace was adaptable to a many-sided and constantly varying production program, involving castings of various high chromium, chromium-nickel and chromium-molybdenum alloys for heat resistance or corrosion resistance. In this class of work the crucible is severely attacked. Linings made of a German siliceous refractory clay will give 40 to 60 heats when melting clean scrap into alloy castings when silicon need not be restricted. With straight carbon steel castings the crucible life is 80 to 100 heats; with high carbon steels of lower melting point it is practically unlimited. Basic linings made of a prepared material called "magnesidon" have lasted from 160 to 200 heats of low carbon, high chromium alloys. Use of special, patented mixtures becomes one of economics whenever local refractories can serve to produce metal of required analysis and quality.

While it is possible to tamp the crucible within the furnace coil itself, it is our practice to mold, tamp and dry a new crucible ready for insertion when the time is right. After the last heat, the old crucible is drenched with water, broken up, and removed through a hole in the bottom of the permanent furnace structure, cleaning the copper coil meanwhile. This takes 10 to 15 min. The new crucible, carrying its inner templet, is lowered in place and loose asbestos tamped in the thin space between it and the coil. The inner templet is then removed, and a course of closing bricks laid around the top. This work consumes 30 to 40 min. more, so the new crucible is ready for a charge (which is carefully placed) within an hour at most. Electrical energy is put into this first heat at a slow rate in order to "burn in" the refractory material in contact with the molten metal. Cost of labor, one hour delay and refractory material (550 lb. for a 2½-ton furnace) may then be divided by the expected number of heats.

Other items of operating cost may be cited, over and above the interest and amortization of the furnace plant and electrical auxiliaries. Current requirements are 430 to 500 kw. per ton of clean scrap melted. Low figures are for high carbon, low alloys; high figures are for low carbon, high alloy castings. New users of these furnaces are apt to strive for minimum current consumption. Soon, however, it will be apparent that the quality and yield of product is the prime consideration, more important than an extra power consumption of, say, 100 to 150 kw. per ton of finished material. Current consumption during the melt depends on the bulkiness or compactness of the charge, and therefore German managers are reconciled to rather wide limits. Refining will require from 50 to 200 kw. per ton additional.

Using clean scrap and acid crucibles, the oxidation loss in metal is 3%. Filtered cooling water required in the primary coils of a ½-ton furnace is 3 gal. per min.; 4½ gal. is needed for a 1-ton furnace; a sufficient quantity must be used to keep the outgoing temperature below 140° F. and thus prevent the breakdown of bicarbonates in solution, which would fill the copper coils with scale.

If the motor-generator power is correctly adjusted to the crucible capacity, melting will be complete in 40 to 50 min. Refining or superheating (if desired) depends on the specific metallurgical requirements, but needs from 15 to 45 min. —the latter the maximum for low carbon, high alloy heats. Gray iron molds, cupola melted, have a life of 50 to 70 pours. (It is interesting to record that old molds, cupola melted, simply remelted and superheated in the induction furnace to give a fine graphite distribution, lasted three or four times as long.)

Heat and material balance has been studied since the first. Our average figures for the former are as follows.

Conversion losses	17.5%
Condenser losses	3.0
Coil losses	8.0
Radiation	1.5
Useful heat	70.0
Total	100.0%

It is easy to become too enthusiastic about the high frequency furnace. Careful economic studies will be needed to show what types of material it can melt in competition with the older equipment. High frequency furnaces are completely out of the question, for example, in the making of very large gray iron castings, as the largest European unit at the time of writing has a capacity of only 8 tons. For smaller castings, even of ordinary analysis, it will bear investigation whenever particularly severe specifications must be met.

CRUCIBLE TOOLSTEEL

its manufacture

By H. C. Bigge
Superintendent Toolsteel Dept.
Bethlehem Steel Co.

IN THE October issue of METAL PROGRESS (page 455) the author presented some information on the "Historical Development of High Speed." Discovery by Taylor and White of the heat treatment necessary for red hardness was made in the Bethlehem plant. While the toolsteels of the present day are manufactured almost exclusively in electric furnaces, any complete account of the art should tell of the crucible process, which was supreme at the turn of the century.

Production of iron and steel by a crude variety of the crucible process was doubtless practiced thousands of years ago, but modern toolsteel had its beginning in 1740, when Benjamin Huntsman of Sheffield, England, revolutionized the art of steel manufacture by melting broken pieces of carburized iron in a crucible, thereby obtaining a more uniform metal. The first toolsteel company was established in 1751.

Prior to Huntsman the best steel was "blister steel" — that is, wrought iron that had been properly carburized by long heating with charcoal in a box. Single bars of blister steel could, of course, be forged into various shapes; in them a higher carbon surface was underlaid with a lower carbon core. Sometimes several such flat bars were welded together, forged into a flat and the process repeated several times, producing a fine laminated structure — the beautiful "Damascene" blades. In any case, real uniformity was lacking until Huntsman's time.

Eventually refined iron was substituted for blister steel in his crucible mix and charcoal was added as a carburizer, and the mixture was melted to "cast steel," as it was called. From that point progress in toolsteel was slow until the advent of modern analytical chemistry and electric furnaces.

According to Professor Goodale's "Chronology of Iron and Steel," the first American toolsteel of high quality was probably made by Hussey, Wells and Co. in Pittsburgh from American iron in 1860. Doubtless the furnaces were a close copy of the English ones of the day. The first furnaces used in Bethlehem were old-fashioned "melting holes" holding four pots, embedded in anthracite or coke. By 1900, however, Siemens' regenerative furnace, or some modification, was widely used in the United States.

Usually this furnace had a capacity of 36 pots (each accommodating slightly less than 100 lb. of steel) arranged in groups of six. Each of the six melting compartments was covered with three brick-lined steel frames which could be removed individually for charging and pulling the pots. Regenerative gas and air chambers were arranged on either side of the melting holes.

16-In., 3600-Lb. Modern Ingot of High Speed Steel

The fuel, natural gas or producer gas, usually the latter, was fed into the gas chambers by valve control, and air was sucked in the air chamber by controlled stack draft. Twelve ports, two on opposite sides of each compartment, served as outlets for the gases of combustion, and the flow of gas was reversed in direction every 20 min.

The furnace chamber rested on cast iron bedplates, supported at the sides by the foundation wall of the gas chamber, and protected from the heat by heavy bricks covered with a

The Puller-Out Swathed in "Rags" to Protect Him When he Straddles the White Hot Melting Hole. Read "Steel-Makers" by Harry Brearley for an intimate view of the men and the crucible process

12-in. layer of coke breeze. The latter served as a cushion for the pots and aided in maintaining an even temperature.

Pots were made from a mixture of natural flake graphite, ball clay, and silica sand, thoroughly mixed, ground, and spun to shape. Making and drying of these pots was a fine art. Six heats every 24 hr., or 30 heats per week, were made in a crucible furnace. The remainder of the time was spent on repairs and to condition the gas producers and the furnace proper. Ingot recovery from a 36-pot furnace averaged about 3420 lb. per heat.

In crucible melting all ingredients were added to the original charge. Once a pot became sealed by the flaking action of the cover, it was rarely removed or opened until the steel was ready to teem. In fact, exclusion of atmospheric gases during the entire process was one of the reasons for the high quality of the steel. About three hours was required to melt a charge of ordinary carbon steel. After a period of "dead melting," the heat was then ready to be pulled. One furnace cover was removed, exposing only the two pots below. These were lifted out by hand tongs and passed to the "teemer" who poured the metal into an ingot mold or holding ladle.

The total weight of the crucible and the tongs was about 150 lb., and the operator had to swath his legs and arms, straddle the furnace opening and make a lift of almost 3 ft. directly upwards — certainly no job for a weakling!

As soon as the steel had been poured from the pots, they were filled with a new charge and trundled back to the furnace on small buggies. The average life of a pot was about eight heats.

Charcoal in small bags, red brick dust (silica clay), rock salt, and ferromanganese were placed in the bottom of the pot, followed by all of the iron. Steel scrap, which has the lowest melting point, was placed at the top. The charge was then packed thoroughly by mechanical shaking devices to insure a tight fit of the cover. This was an important detail.

The process was not one of refining, so sulphur and phosphorus could not be removed. Raw materials had to be carefully selected, practically all crucible mixes being based on puddled or charcoal iron, reasonably free from slag inclusions. Removal of rust by tumbling or sandblasting was a valuable preliminary, and recharged steel scrap had to be clean. Hardwood charcoal of pea size screened from dust was used. Ferromanganese was of the low carbon variety, in small lumps of uniform size.

The melt-down was accomplished rather quickly in a hot furnace. Gas and air were adjusted for complete combustion or a slight excess of fuel, and the furnace was operated to melt and clear the steel in about three hours. Another was required for killing and dead melting the steel. During this important operation the furnace was operated on the hot side for the first half hour, and then gradually tapered off to the cool side. This operation served to deoxidize and degasify the metal and to allow non-metallic inclusions to rise to the top. During this period the molten steel also

absorbed carbon and silicon from the pot in amounts depending upon the time, the temperature, and the composition and age of the pot. The reduction of silica and the absorption of silicon made conditions very favorable for complete deoxidation of the steel.

Long and thorough training was required before the melter could determine when the steel had sufficient "fire" to rid it of nonmetallic inclusions and dissolved gases. To aid in this determination he poked a low carbon iron rod into the pot. The rod was then plunged in water and the adhering slag examined.

Traditionally One Potful to an Ingot, but Large Ingots Were Conveniently Teemed From a Holding Ladle

Too little fire was indicated by a prolonged burst of sparks upon removal of the crucible cap. Too much fire gave an ingot a leady structure and a "dry," dull appearing bar fracture. Excessively high temperatures were also accompanied by a display of sparks, but the experienced melter was able to determine by the poker and slag test whether the wildness was due to insufficient deoxidation or to a superheated charge.

The term "refining," as applied to the melting of toolsteel, usually implies the removal of undesirable impurities such as phosphorus by oxidation or sulphur by reduction in the presence of a basic flux. In crucible melting such a refining was impossible because the pot, although reducing in action, was also of siliceous or acid nature, which necessitated the use of an acid slag of glass or sand. Oxides and dissolved gases were removed by interaction with silicon, absorbed from the pot in amounts as required and under ideal conditions to insure complete deoxidation. Carbon in the proper form was absorbed slowly from the charcoal to produce stable carbides of a nature highly desirable for solution and uniform distribution in the finished steel.

If the carbon occasionally varied slightly from the desired content, this could be corrected in the following heat by adjusting the amount of charcoal. There was always a pickup in carbon beyond that introduced as charcoal due to the fact that the pot contained more than 50% by weight of flake graphite. Variations depending upon the number of heats made in the pot could be taken care of by proportionate increases in the amount of charcoal used in the later heats. Time and temperature during the killing or refining period likewise affected the carbon pickup. This varied considerably unless operating conditions were held uniform by the melter. In fact, carbon uniformity from heat to heat was usually a good gage of the skill of the melter, and was quickly determined since the end of each bar was broken off to test soundness and "temper."

Proper temperature for teeming was also largely a question of experience and skill. When the killing or refining period had been sufficient to give the steel the proper silicon content, and when the temperature was correct, the steel was ready to pour.

The reducing condition of the crucible process permitted the introduction of easily oxidized elements such as chromium and vanadium without excessive losses. Conditions were also favorable for dissociating any iron oxide.

It is thus evident that the crucible process was essentially a remelting process, and that the analysis of the final product depended upon the material charged. The only metallurgical purification was a reduction of contained oxides and a removal of mechanically included impurities. Nevertheless, for almost two centuries the product of the crucible process maintained its enviable record of quality, challenged only by the product of the carefully controlled electric arc furnace and coreless induction furnace.

HIGH GRADE ZINC

electrically smelted

By W. S. Landis

Abstract of paper before American Electrochemical Society, 72nd Meeting, St. Louis

ELECTROTHERMIC REDUCTION of zinc has been studied extensively for a long time by many investigators as a substitute for the time-honored distillation, in small retorts, of a mixture of relatively pure zinc oxide and carbon. The batch-retort system seems an antiquated method of producing large quantities of metal. An installed retort produces, on the average, only 30 lb. of zinc per day. While they are built in blocks, each retort must be serviced as a unit; the heating, which is done by gas, is **en bloc**. The large thermal requirement of the reduction reaction must all be passed through a refractory retort of low heat conductivity; fuel efficiency is naturally low. The retort maintenance and replacement are considerable even when great care is exercised in the choice of ores neutral to the retort material.

To the electric furnace engineer the distillation of zinc would seem to be a tailor-made proposition. Linings are no problem and choice of ore from the standpoint of attack on refractories need not be considered. The heat is generated directly in the charge and can be supplied at any rate desired. Top temperatures are no problem for we are no longer concerned with the softening of a retort wall. Non-volatile residues are no trouble, for they can be fluxed and tapped out as a slag. The presence of residual sulphur in the roasted ore is of little concern, for it can be converted to an iron or copper matte and, as such, used as a collector of any precious metals that may be present. In short, almost any sort of zinc ore may be used.

Our own work was done at the Trollhättan Electrothermal Co.'s plant in Sweden, which had been smelting zinc in a number of small single phase furnaces, and consisted largely in perfecting the processes we found there. Our three-phase furnace smelted up to 100 tons per day of charge, the residue being slagged off. The zinc vapor leaving the furnace carried with it moisture, entrapped air and volatile foreign elements, not to speak of dust, and, in consequence, was much diluted as compared with retort vapors. We, therefore, knowing the adverse conditions to be faced, adopted the older practice of DeLaval and decided to condense as a powder. For such condensation a rapid drop in temperature is all that is required. The upper part and roof of the condenser were of brick; the sidewalls and hopper bottoms of steel. The volume was 2330 cu.ft. Sidewalls were water jacketed, and inside were several water-cooled plates. Condensed powder was removed by screw conveyor.

The whole system was airtight, and vapors were discharged through a water seal. To prevent air being sucked in and forming explosive mixtures if the furnace stopped smelting, a small gas generator was connected as stand-by, always ready to flood the chamber instantly with very dry gas of low free oxygen content. Electrodes entered the furnace through water-cooled seals; power was regulated by tap-changing switches so electrodes were fed only one way, downward.

Zinc powder from such a process analyzes 70% metallic zinc, 20% zinc oxide and 10% lead, cadmium and dust. This large amount of zinc oxide present is a real problem, showing the importance of eliminating all sources of oxygen from the charge — that is, oxygen present as sulphates, as moisture, in incompletely burned lime, and in the higher oxides of iron.

The powder removed from the condensers followed the general metallurgical process of the Trollhättan plant; that is, it was sent to a special rotary furnace, electrically heated to low redness, and under the combined action of the temperature and the rolling action of the furnace 90% of the zinc was converted to liquid metal. The remainder, together with the oxidized portion and the other impurities, was continuously discharged and returned to the ore smelting furnace. Feeding was continuous. At intervals the furnace was stopped and the liquid metal tapped off. Some eight resistors of carbon, arranged parallel to the axis and midway between the center and the circumference, connected in series and to a pair of slip-rings, furnished the heat.

This zinc, after lead and zinc-iron had been liquidated, corresponded to our Prime Western grades, and was marketable as such. Redistillation was done in a box-shaped furnace, heated by a single phase arc, centrally placed between horizontal electrodes entering the sidewalls. There was no complicated condenser problem in this treatment, for the vapors were practically 100% zinc.

As carried out at Trollhättan, the zinc smelting from ore to refined metal involved four major steps, each an electric furnace operation, namely, smelting, powder agglomeration, liquation, redistillation. Had the work been continued [the Editor understands the plant has been dormant since 1936] I am certain two of these steps would have been eliminated. The powder would have been redistilled under closely controlled temperature, producing high grade zinc and leaving behind a comparatively small amount of lead and "hard zinc" to be cleaned up in separate operations.

WELDING OF CAST IRON

discussed at Birmingham

As reported by
Raymond L. Rolf
Metallurgical Engineer
Lakeside Steel Improvement Co.
Cleveland

FROM the commercialization of calcium carbide in 1892, passing time has seen this industry expand from an early market devoted to house lighting, miners' lamps, Bunsen burners, and the early oxy-acetylene blowpipe to the more recent efficient applications of acetylene to automatic welding operations and flame cutting machines. The chemical industry consumes many thousands of tons of carbide — the equivalent of millions of cubic feet of acetylene — in the manufacture of chemicals from which such diversified materials as rayon, synthetic rubber, plastics, solvents, dyes, perfumes, safety glass and photographic films are produced.

So enormous is this industry with all its various ramifications that 1,133,824,000 cu.ft. of acetylene was produced in 1935. If all of this acetylene were used in making circumferential welds on 40-ft. lengths of 12-in. pipe, the resulting pipe line would extend over 250,000 miles, more than enough to reach from here to the moon. If all the acetylene were compressed in cylinders, it would take 6,750,000 to handle it (allowing for a 45-day turnover). Based on the average weight of steel in these cylinders, their production represents an original shipment of 385,000 tons of steel, or 19,000 carloads.

These interesting facts were revealed by C. D'W. Gibson, president of the International Acetylene Association, in his address before the 38th annual convention held in November in Birmingham, Ala.

At the opening session H. Sidney Smith was awarded the James Turner Morehead Medal for his vision, inspirational guidance and aggressive cooperation in the advancement of the acetylene industry. Mr. Smith had only last month received the Samuel Wylie Miller medal of the American Welding Society; his other well-deserved honors are noted in METAL PROGRESS last month (page 645).

Pipe Welding

Inasmuch as pipe welding in all its phases has experienced a year of unusual development, several papers devoted to this subject were of timely interest. O. B. McLaughlan of Freeport Sulphur Co. pointed out several unusual methods in constructing pipe lines for steam, hot water, and sulphur solutions in the low and swampy lands of the Mississippi delta, where transportation of men and material is entirely by means of boats and barges. As some settlement of the piling-supported buildings and trestles was expected, and also on account of the

high pressures and temperatures of the fluids transported through the piping, welded joints were the natural selection of the engineers in charge of the work.

Three 20-ft. lengths of pipe were welded at a receiving yard at Freeport, Texas, to form 60-ft. sections, then shipped by barge to Port Sulphur. On arrival the pipes were scraped and painted and two of these lengths were welded together making a finished section 120 ft. long. These were taken by barge to their position in the line, and moved into position (usually on trestle work). A tacking crew then aligned and tacked the entire line with the exception of channel crossings. Following these and working from a barge were the welding operators. Using this system, three welding operators would close the field joints on approximately 1800 ft. of pipe line per day.

When all jointing was completed, a hydrostatic pressure of 500 psi. was imposed on the system, after which it was subjected to a 200-lb. steam pressure. The lines were then allowed to cool and condense the steam, creating a vacuum. These tests revealed only three leaks.

J. T. Mackenzie, metallurgist of American Cast Iron Pipe Co., pointed out the importance of a dependable and serviceable method of welding cast iron pipes with either plain or bell ends, and outlined his extensive experiments on the bronze weld and cast iron fusion weld. He pointed out that the bronze weld does not lend itself to the standard method of impact testing, as the bronze is soft and ductile, and cushions the blow of the hammer. From all indications the bronze weld had no weakening effect on the impact resistance of the pipe itself; likewise the weakening effect of the cast iron fusion joint was slight.

Galvanic action is an important factor in the corrosion of welds, it being the speaker's opinion that it is impossible in any welding operation to produce a metal with exactly the same structure as the parts welded. When mixed structures are exposed to an electrolyte, galvanic currents will be set up which will cause attack at the anodic areas. Galvanic action of this type becomes serious only when the positive or anode is small in area as compared to the cathode. For instance, where a brass or bronze coupling is used to join iron or steel pipe, the coupling is cathodic, causing the *pipe* to corrode. This corrosion is spread out over a large area and is usually not severe at any one point. However, where brass or copper piping is joined by a coupling of ferrous metal the galvanic attack is concentrated on the anodic coupling, usually destroying it in a short time. If the cathode is small in area as compared to the anode, the reaction is cathode-controlled, that is, the progress of the reaction is governed by the amount of oxygen available to remove the hydrogen formed, and to depolarize the cathode. Thus, where the reaction is cathode-controlled, the amount of corrosion is very much less when the gas (air or oxygen) content of the liquid being handled can be minimized.

C. L. Lane, works manager of the Attalla (Ala.) plant of Walworth Co., showed the advancement made in cast iron pipe, describing three standard analyses available for varying degrees of corrosion severity in diameters 1¼ to 8 in. Demand for lengths of five feet led to

the development of a process of "multi-lengthening" by oxy-acetylene welding, which he described in detail. In these cast irons it is necessary to remember that the tensile strength and ductility are much lower than in steel, which makes it obligatory that the entire periphery of the weld be heated and cooled at as nearly uniform a rate as possible. Contrary to some opinions, Mr. Lane finds that it is not necessary to preheat the entire length of pipe — merely keep the weld hot, as it is completed, until the entire joint has been finished.

Most difficulty with welding cast iron pipe in the field arises from the failure to cool the weld uniformly, or failure to "get to the bottom" while welding. It is not sufficient simply to melt the metal from the rod into the space between the beveled ends; the metal of the pipes must actually be heated to the fusion point and melted for a depth of about $\frac{1}{16}$ in. all the way down to the bottom of the bevel, at the same time adding molten metal from the welding rod so that it unites with the fused metal on either side.

Flame Machining and Hardening

Rapidly coming to the fore as a machine tool is the acetylene torch. Remove it from the industry and we will retrogress, for no other tool has the versatility which permits our modern designs, and makes production per man-hour double that of 30 years ago. Splendid papers by A. E. Gibson of the Wellman Engineering Co. and R. F. Helmkamp, Air Reduction Sales Co., pertain to this wide, expanding field.

An oxy-acetylene cutting torch will form contours so complex that if the parts were produced by any other method now known the cost would be prohibitive. The freedom by which shapes may be cut makes it possible to produce contours of exact dimensions, free from sharp corners, thus eliminating points of excessive stress concentration. There appears to be no limit in design of a structure when a cutting torch is used. The component parts, after cutting, may be flanged or pressed into whatever shape is desired. Details may be cut out so that only a minimum amount of finish machining is required. Where plates and shapes are to be welded, they can be so accurately fitted that up to half the welding labor can be saved over that required when using details which do not fit as closely as they should.

An interesting application of the cutting flame — namely, deseaming of steel billets — was discussed at some length in the report of the Oxy-Acetylene Committee, presented by George V. Slottman, Air Reduction Sales Co., New York. This may be done by hand, removing only those portions of the surface indicated by an inspector (as described in detail by E. E. Thum in METAL PROGRESS for May 1936). By mounting a number of scarfing torches on a carriage, whole surfaces on blooms of any desired width — or group of small ones placed side by side — may be removed at speeds of 2 ft. per sec. or faster.

H. H. Moss of the Linde Air Products Co. has made a very comprehensive study of the effects of oxy-acetylene cutting on the physical properties of certain steels. He points out that several of the so-called low alloy, high strength structural steels may be flame cut quite satisfactorily at normal temperatures — for instance, the low manganese silicon structural steels in thickness not exceeding $\frac{5}{8}$ in., providing the carbon content is on the low side. Low carbon, chromium, phosphorus steels and other strong steels in this class employing small amounts of nickel and molybdenum in the lighter gages are also not seriously affected by flame cutting.

This research work on the effect of flame cutting on the physical properties of metal in and marginally below the cut surfaces in a number of popular grades of carbon and low alloy steels is undoubtedly an outstanding contribution to the industry. Constantly an over-cautious structural or mechanical engineer is raising the point that flame cutting injures the metal so badly that the surface must be removed by machining, whereas it has been frequently demonstrated that the flame cut surface on common structural steel will withstand more severe bending and other tests for quality than a surface machined with normal cuts and feeds.

Closely allied with the cutting torch is the process of flame hardening. The paper of John T. Howat, American Spiral Spring & Mfg. Co., Pittsburgh, dealing with torch hardening applications and the paper and motion pictures of R. L. Rolf of Lakeside Steel Improvement Co., Cleveland, covering the mechanization of this process show the revival and widespread application of the old Shorter process, and illustrate vividly how the oxy-acetylene flame may be adapted as a heating medium in an operation related metallurgically to the widely used furnace hardening method. It is perhaps unnecessary to expand this point in view of its adequate treatment by A. K. Seemann in METAL PROGRESS, September issue.

ECONOMICS OF WELDING

By C. C. Brinton

Abstract of paper read before American Society of Mechanical Engineers, Atlantic City, Oct. 19, 1937

ECONOMICAL substitution of weldings for castings is not solved by balancing the cost of steel plate at 2¢ per lb. against a rough casting at 6¢. It is better to think of cast iron or steel ready to pour, and steel plates and shapes ready to be cut and formed to shape, as the raw material in each case and build up from there the final cost of each type of structure to be manufactured. In any case it is necessary to consider whether the left-overs from the structural shapes and plates can be utilized or merely have value as scrap. With a reasonable activity, we have been able in the Westinghouse generator division to establish a standard ratio to use for such material, as shown in the table for a typical month of 1937.

In order to keep the amount of scrap within or less than the average ratio, it is necessary to choose the stock sizes to suit those of the largest activity, and to order special sizes for large parts or a big order. Unfortunately, there are not enough small pieces required for our type of fabricated structure to allow the greater part of the scrap to be used, and it requires close supervision even to use portions of plates economically.

The problem of assembling parts together in the minimum time and with sufficient accuracy that excessive weld material will not be needed can only be solved by cutting and forming the pieces to *exact* size and shape. Careful layout before cutting is necessary, using sheet steel templets where enough pieces of the same shapes are required, prick-punched at a few places so that the cutting may be checked easily. In many cases it is possible to cut the part out of the large plates without cutting through the outside boundaries and avoid some of the distortion from the cutting torches.

In order to arrange the work most economically, the cutting, grinding and trimming have been segregated from the assembly and divided into certain classes so that a group always does the same class of work. In like manner the assembly before welding is divided into several classes so that each group handles only one class of work.

When assembling and tacking for final welding, steel surface plates are used that are sufficiently massive and accurate to keep the structure level and allow them to be aligned properly. Enough tack welding is applied to hold the structure in shape and to move it to another location for final welding.

Since one of the main savings in cost is in eliminating some of the final machining operations, it is necessary to use fixtures for holding parts in place while assembling and welding and to avoid distortions by the proper welding procedure. It is desirable to design parts so that most of the welding may be done by automatic machine and advantage taken of the lower costs and more reliable welding.

Many welding operations cannot be made with the automatic equipment and it is then desirable to provide handling fixtures to aid the operators to position the pieces for downhand welding.

The amount of weld metal to be deposited usually varies directly with the number of pieces to be welded together. Therefore this has influenced design to a greater extent than the placing of parts to facilitate welding and assembly. Where weight limitations will allow, it is usually found more economical to use plates of sufficient size so that they do not require supports or braces for stiffness. In many cases it is cheaper to form or bend the lighter plates rather than weld on extra pieces.

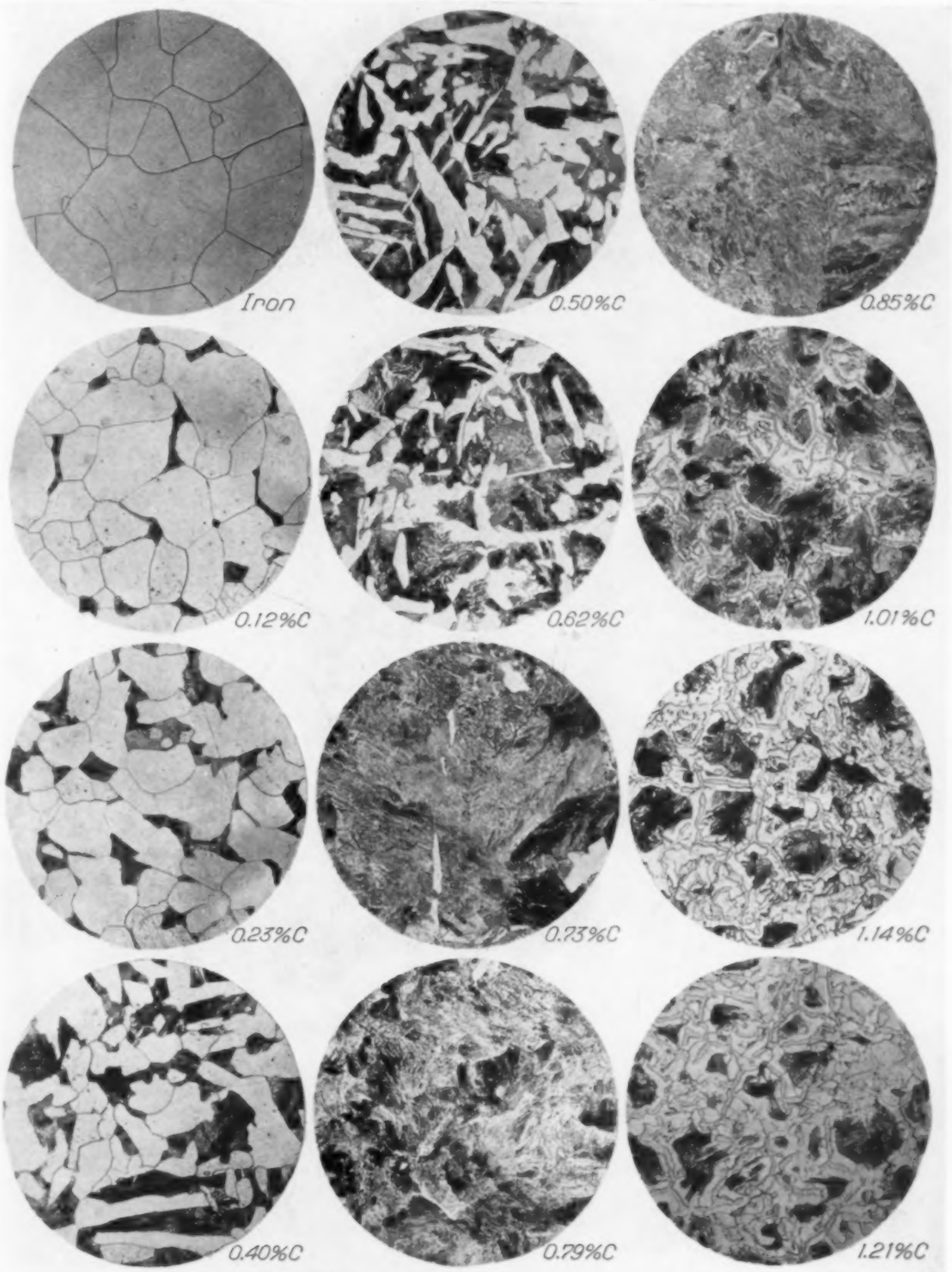
Although much progress has been made in constructing economical machine parts by welding, the development of better assembly and handling methods and the design of simpler structures offer more chances of further savings than the actual application of the weld metal, even though we are still making satisfactory progress in developing welding rods for satisfactory work at greater speeds.

Raw Material Utilized in Weldings

	Amount Received	Consumed	Scrap	Utilization Ratio — Actual	Utilization Ratio — Av
Plate	1,565,000	1,002,000	563,000	1.56	
Slabs & bars	356,022	317,572	38,450	1.12	
Shapes	236,489	226,509	9,980	1.04	
Total	2,157,511	1,546,081	611,430	1.40	

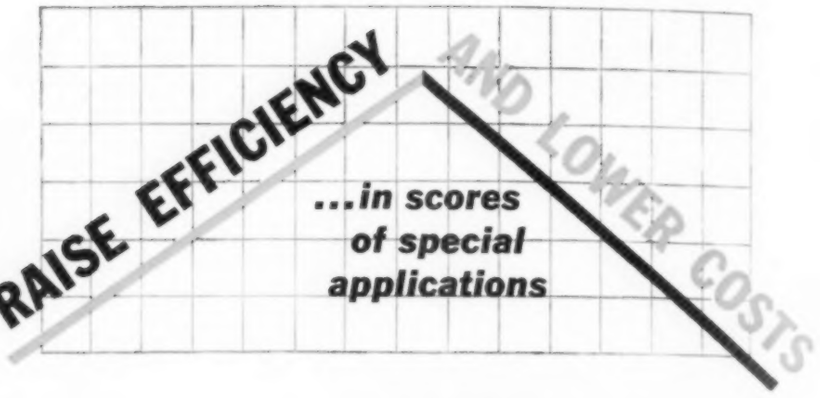
High Purity Iron-Carbon Alloys

Micrographs at 100 dia. by Harry K. Herschman, metallurgist, National Bureau of Standards

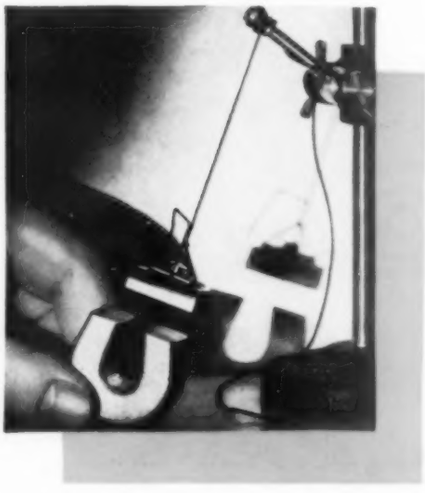


Specimens prepared by Thomas G. Digges (see Preprint No. 3, 1937) by carburizing vacuum-fused electrolytic iron in a mixture of hydrogen and benzene vapor, then annealing in vacuum one hour at 1700° F. (925° C.). Total impurities by analysis, less than 0.03%. Etched in mixture of equal parts of 1% HNO_3 in alcohol and 5% picric acid in alcohol. Publication approved by director of Bureau of Standards.

HIGH NICKEL ALLOYS



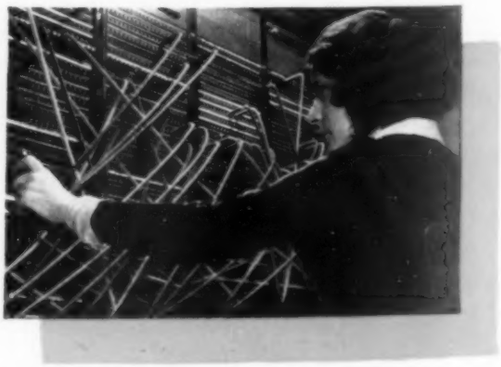
HIGH MAGNETIC QUALITIES... The magnet pictured here is small, but extraordinarily powerful—capable of lifting 60 times its own weight. This particular type, made of a new alloy rich in Nickel, is used for damping magnets in the polyphase meters of the Duncan Electric Co., Lafayette, Ind. Not only do these alloys of high Nickel content effect substantial savings in weight (in this case 80%) but they also have a higher permanency factor than other commercially available magnetic materials and are practically immune to the effects of magnetic disturbances caused by short circuits and lightning. Manufacturers who employ magnetic materials in their products will find these new alloys of Nickel profitable to investigate.



HIGH AND LOW EXPANSION PROPERTIES...

One of the most valuable metallurgical developments in recent years has been the production of thermostatic metals for operating automatic control devices. Pictured here is one employing a bi-metallic disc made of two alloys of Nickel, one having a high degree of expansion and the other low expansion properties. It guards the Westinghouse refrigerator motor, disconnecting it when it gets too hot and reconnecting it when it cools off. Principle upon which these thermostatic metals operate is based on a differential in the expansion properties of the two constituent metals. Changes in temperature cause them to deflect and this in turn acts on the control device. Alloys of Nickel can be produced for applications requiring extremely low expansions as well as for service where specific expansion characteristics may or may not be low.

IMPROVED PERMEABILITY... When you make your long distance telephone call or send a cable, a highly magnetic Nickel-Iron alloy of improved permeability containing up to 80% Nickel helps to deliver your message. Impulses sent over long circuits have a tendency to drag their "tails" behind them, upon which succeeding impulses tread. But through the use of loading coils made of a high Nickel alloy, and spaced at regular intervals along the circuit, transmission is speeded up and your words made intelligible. The high magnetic permeability of these alloys is also depended upon to increase the efficiency of submarine cables and various parts of radio, telephonic and telegraphic installations. We invite consultation on the use of the Nickel alloys in your equipment.



THE INTERNATIONAL NICKEL COMPANY, INC., NEW YORK, N.Y.

CORRESPONDENCE

from home

and abroad

Precise Control of Atmospheres

required to prevent surface reactions

CONSETT, ENGLAND

To the Editor of METAL PROGRESS:

The article by F. M. Reiter on the controlled hardening of tools in METAL PROGRESS for September 1937, contains some interesting remarks on the mechanism of decarburization. Among other things, it is there observed that both carburization and decarburization can be obtained with natural gas. Some years ago, in experimenting on the deoxidation of steel with hydrogen, the writer noticed that when a slow current of dry hydrogen was passed first over a polished specimen of a mild steel plate and then over a similar specimen of Armco iron, the surface of the steel was decarburized and that of the Armco carburized to a considerable degree. (Details were given in a paper on the deoxidation of steel by hydrogen in *Journal* of the Iron & Steel Institute, 1920 — II, p. 143).

The hydrogen used was generated by the action of hydrochloric acid on pure zinc and dried by passage through soda lime, calcium chloride and finally phosphorus pentoxide. Some further similar experiments were subsequently done and it was then found that if the hydrogen was first passed over burnt lime instead of soda lime, the Armco was not carburized. If calcium carbonate was used, instead of burnt lime, carburization of the Armco and decarburization of the steel occurred as had been described. It seemed clear, therefore, that in the first experiments a trace of carbon dioxide had been included in the hydrogen during its passage through the soda lime.

Since that time the writer has done no further work in that direction, but these observations seemed worth recording, as they clearly indicate that, in the first place, under the same conditions various steels can react differently in hydrogen, and in the second that the reaction is very sensitive to small variations in the purity of the gas.

JOHN H. WHITELEY
Consett Iron Co., Ltd.

Evolution of Gun Steel

PARIS, FRANCE

To the Editor of METAL PROGRESS:

Gun steel must be resistant not only to wear but also to impact, and experience acquired during the War showed the importance of the latter. In firing, the surface of the bore develops a network of cracks, microscopic at first, but eventually becoming visible. Their origin is attributed, since the time of Tschneroff, to quick changes of temperature. The lamented Henry Marion Howe made a classical study of these cracks, published by the American Institute of Mining and Metallurgical Engineers about 20 years ago. Such cracks may also be found in various modifications in other metallic parts subjected to analogous effects, such as mill rolls, die casting molds and glass molds, as well as metal brake drums.

These cracks, at least at first, are often concealed by the penetration of copper from the shell bands, but they may be disclosed by proper etching in acid.

Their formation involves numerous properties of the metal — expansion, thermal conductivity and diffusibility, capacity for deformation, thermal transformations and anomalies, and probably others. A systematic study of glass molds (by MM. Bauret and Chevenard with the present writer) revealed that considerable delay in the appearance of this phenomenon could be obtained with iron-nickel-chromium-tungsten alloys, but these have not yet been used for guns. In any event, surface cracking in the bore of guns seems to have some connection, if it is not actually induced, by the presence of a network of ferrite in the metal, which should therefore be avoided.

Because this weblike cracking is present after a few rounds are fired, gun steel should have high impact resistance when notched. In exceptional cases failure occurs when metal parts are first placed in service because of an inherent brittleness. In either case, it is the "resilience" as defined by the impact test on a notched bar which is the important factor and should be investigated.

Maximum resilience is obtained in a given steel by tempering to the sorbitic structure (defined by me as a "Widmannstätten structure" in *Revue de Metallurgie,* Vol. XVI, p. 141, 1919) after quenching so that maximum hardness or maximum amount of martensite is obtained. This latter requirement, along with that of avoiding a ferrite network, demands a cooling rate higher than the critical rate for suppressing the Ar′ transformation. In other words, the steel must quench deeply enough to harden the core, or at least to a very considerable depth below the surface.

Machinability must also be borne in mind, for after the final heat treatment the gun is bored and rifled. This removes the superficial layers, and the heat treatment to sorbite must extend well below the depth of the rifling grooves.

Before and during the War, gun tubes were fabricated of semi-hard steel containing only small quantities of special elements (say, 1 to 2% nickel or chromium), quenched and tempered so as to give a tensile strength of about 150,000 psi., and elongation of 10% on samples taken transversely half way through the wall thickness.

Such a steel is not readily hardenable and the treatment increases the tensile strength at depth only a relatively small amount, so that the quenched martensitic zone free from ferrite network is only superficial; furthermore, cooling must be very drastic even for that degree of hardening. The quenching temperature might be raised, but this would increase the risk of overheating and superficial decarburization.

Thus, if resilience is to be increased, hardening must penetrate to the center of the tube walls, and for this purpose self-hardening steels are required.

On the other hand, efforts are being made to increase the range of projectiles which necessitates increasing their muzzle velocity, as well as the gas pressure and the strength of the tube walls; furthermore, attempts to use lighter materials necessitate increased strength in the steels used. All these reasons point to the use of self-hardening steels, steels which will harden to a sufficient depth, or in other words, in which the Ar′ (or Ar″) transformation is suppressed. These steels are also less susceptible to distortion in quenching.

Low alloy steels are therefore being abandoned in favor of self-hardening steels made by incorporating sufficient quantities of such elements as nickel, chromium and molybdenum, adding either two or three of these elements in combination.

For control after heat treatment the resilience should be determined by means of the notched bar impact test, and a particular search should be made for "flakes," a frequent defect in these complex steels with delayed transformations on quenching.

ALBERT PORTEVIN
Consulting Engineer
Electrometallurgical Co. of the Ugine

A Note on Production

NEW YORK CITY

To the Editor of METAL PROGRESS:

While the bulk of ASMembers are doubtless more interested in the technical aspects of metal production and use, it may be important from time to time to present a glimpse of the world's metallurgical industry. Such a glimpse is furnished by the recently issued report of world production of iron ore, pig iron and steel, by the British Iron & Steel Federation.

This shows a world-wide increase of pig iron from 73.10 million long tons in 1915 to

90,19 million in 1936; of steel, from 97.72 million in 1935 to 121.72 million in 1936.

Ore production was 138 million long tons in 1935. All countries have not totaled their 1936 ore production yet. But indicative are the increases in the United Kingdom from 10,895,000 to 12,701,000; in France from 31,548,000 to 32,689,000; in Russia from 26,421,000 to 27,477,000; in Sweden from 7,809,000 to 11,104,000; in the United States from 30,540,000 to 48,618,000.

MYRON WEISS
Associate Editor
Time Newsmagazine

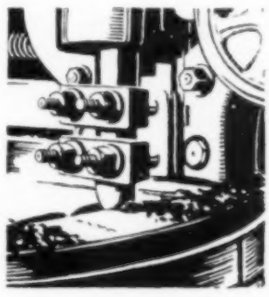
Breaking-In Cu-Pb Bearings

PHILADELPHIA, PA.

To the Editor of METAL PROGRESS:

Metallurgical developments and the application of copper-lead bearings — their advantages and special features — have been adequately and competently dealt with by various writers. It seems to have been taken for granted that many aspects of the lubrication of such bearings are generally known. Yet there is, perhaps, one thing more needed to complete any full survey of the field — namely, a discussion of modern methods of conditioning or breaking-in copper-lead bearings so that full advantage may be taken of all their potentialities for long, efficient service so well described by Messrs. Jenkins, Neave, and Claus in preceding issues of METAL PROGRESS.

It has been said that "break-in oils are seldom used over there [in England and Germany], the term meaning oils containing fatty additions, such as 1% or more of oleic acid." This is an unsafe generalization, for Europeans are still the largest users of fatty oils and compounded mineral oils for engine and machine lubrication. European engineers were, in fact, the last to accept compounded or straight mineral oils as a satisfactory replacement for sperm, castor, lard oils and other fixed oils.



For all ordinary forms of lubrication it is still common practice in Europe to use a percentage of some fat with a mineral oil, regardless of the greater stability obtained by the use of straight mineral oils. From an economic viewpoint this is a condition to be expected in England and in all countries that must import mineral oils, no matter what might be the engineering preference. Naturally, America's growth in production of automobiles and industrial machinery has meant exploitation of our petroleum resources, and a corresponding urge to utilize petroleum lubricants.

So much for general usage abroad. As used for establishing working clearances, fatty additions to mineral oils of low viscosity have had their day in America. They do recur occasionally for some special use, but in the last four or five years it has become general to employ a chemically treated oil for the purpose — that is, if "break-in oils" are used at all.

For the most part, these modern break-in oils are mineral oils of low viscosity (below 300 Saybolt seconds at 100° F.). They contain an addition agent composed of chemicals or compounds such as chlorinated paraffin waxes, fatty alcohols, phosphoric acid compounds, sulphur compounds, and many others, used singly and sometimes in combination. In some cases such addition agents are combined with synthetic fats derived from oxidized paraffin waxes or other adhesive, friction-lowering "oiliness" agents. With such additions the object is to provide rapid wetting-out and better adhesion to bearing metals. Naphthenic-base oils may thus be improved in comparison with paraffin-base oils, which are inherently superior in terms of adhesion, and better prevent wear in the bearings. All bases used today contain such ingredients; the total amount necessary for best results varies within the range of 1 to 5%.

For the purpose of running-in any type of alloy bearing, it is important to know the corrosive tendencies of materials added to an oil because the action of many is much too drastic to be safe with some non-ferrous metals. Such addition agents should be skilfully formulated and combined, or else they will quickly cause excess clearances, and visible corrosion, if used too long.

However, some of these break-in materials are very beneficial in establishing smooth running surfaces between close fitting parts composed of ferrous metals, such as iron pistons and cylinders, hardened shafts and sleeves, iron and steel gears. They reduce the tendency toward scuffing or scoring which will occur when such surfaces are not protected by a film. Ferric chloride, iron sulphide, and other

similar films formed on wearing surfaces by additions of chemicals to the oil, present a chemically "dirty" surface, giving anti-weld protection to areas which are subject to considerable friction.

Inhibitors have been developed to prevent corrosion caused by excessive acid formation in certain mineral oils. Solvent-refined oils from some crudes require such inhibitors. Failures from oil corrosion often occur, although their physical properties indicate, on paper, a higher refinement than similar oils produced by older methods.

It does not follow, of course, that *all* solvent-refined oils are apt to give trouble with lead bronze or other alloy bearings. Indeed, many oils so produced are superior to the same stocks refined by other methods. It is interesting to note, however, that when certain stocks are refined by solvent methods which are not sufficiently selective, oils are produced which rapidly become acid and corrosive in service; and when an inhibitor is added to such oils they eventually form sludges in service anyway, just as they did when refined by the older methods!

In short, petroleum chemists can go too far in an effort to make sludgeless oils by solvent refining certain crudes. They may remove the natural inhibitors in such oils to such a degree that artificial means of controlling acidity are necessary. Obviously it is advisable to effect a compromise and to put up with some sludge formation during use in order to control the corrosive tendencies of such oils.

This modern method of refining is practical and economical for volume output to uniform standards; therefore it is necessary to consider the type of solvent treatment best suited for refining certain stocks that are to be used on modern engines fitted with lead bronze bearings. Inhibitors are added to motor oils by some refiners nowadays, and their use will probably increase as more accurate service data become available.

Mr. Neave's statement that "with ordinary oils the problem is one of acid formation due to oxidation, but with cooler crankcases and the generally improved oil cooling now employed, trouble need not be expected," would probably be accepted by many automotive engineers in America, but in this our experience would dictate otherwise. When tin-base bearings will not stand up, alloy bearings will — in many instances. This would be excellent if the matter ended there! But the cycle starts all over again when further increase in engine output takes place while using the same bearing areas. As a consequence, oil temperatures go up, and additional oil cooling becomes necessary, though not often provided until manifest trouble occurs. High loading makes lead bronzes preferable to tin-base bearing metals; and therefore, to improve oil life and to keep the acid down, more consideration should be given to *controlled* oil temperatures — not merely oil cooling.

With high-output engines of compact design and small bearing areas, this is a very pertinent problem, for temperatures seriously affect the rate at which the oil will decompose. Those who have experienced real bearing difficulties seem to be impressed by the probable oil-film temperatures attained *within* the bearings under peak loads. Crankcase oil temperatures alone are not a sufficient guide for our needs, as practical tests reveal.

Several large manufacturers now use chemical addition agents for running-in engine and machinery bearings. Thus working clearances are established safely and in a much shorter period than previously accomplished by additions of oleic acid, lard oil, castor oil, and others, to the mineral oil. The distinct advantage of a modern treated oil lies in the fact that the desired result is obtained without "gumming" or carbon formation, both of which occurred when using fats. Furthermore, separation of fats from the mineral oil, in use and in storage, is eliminated. Lower oil temperatures — often to the extent of 15° and even 20° F. — are recorded by the use of such products. Dynamometers record lower friction as indicated by fuel savings of from 1½ to 3%.

In conclusion it may be said that lead bronzes and other modern alloy bearings are best protected and made ready for service with a good mineral oil plus suitable addition agents. To minimize bearing failures from corrosion, it is unsafe to use oils which readily form acid in service; therefore their tendency to produce corrosive acid should be found by actual tests in the machinery itself. Laboratory tests for oil stability and corrosive tendencies cannot accurately encompass all the conditions encountered by an oil in service, nor should one assume that the addition of any one base will improve an oil that is stable to begin with. Some materials available for treating oil are totally unsuited for use with lead bronze bearings.

C. P. GEEN
Manager of Lubrication Research
E. F. Houghton & Co.

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PERSONALS

William P. Woodside, Jr., formerly with Timken Steel and Tube Co., is now Ohio representative for Park Chemical Co. with headquarters in Cleveland.

Curtis W. Dollins has been appointed special research assistant in engineering materials, University of Illinois.

Appointed associate professor of metallurgy at Purdue University, **D. E. Ackerman**, formerly in the Development and Research Division of the International Nickel Co., will have general supervision over instruction and research in physical metallurgy.

Warren D. Fuller has been appointed New England representative for the Selas Co., Philadelphia, with offices in Hartford, Conn.

Promoted to new positions at Gary Works of Carnegie-Illinois Steel Corp.: **R. A. Peterson**, superintendent of the merchant bar mills; **C. S. Ramsay**, assistant superintendent of the merchant bar mills; **S. R. Stanier**, superintendent of the hot strip mills; **R. B. Lucas**, superintendent of the wheel and axle mills; **George Tree**, superintendent of maintenance, west division; **S. L. Moffatt**, superintendent of No. 4 openhearth furnace.

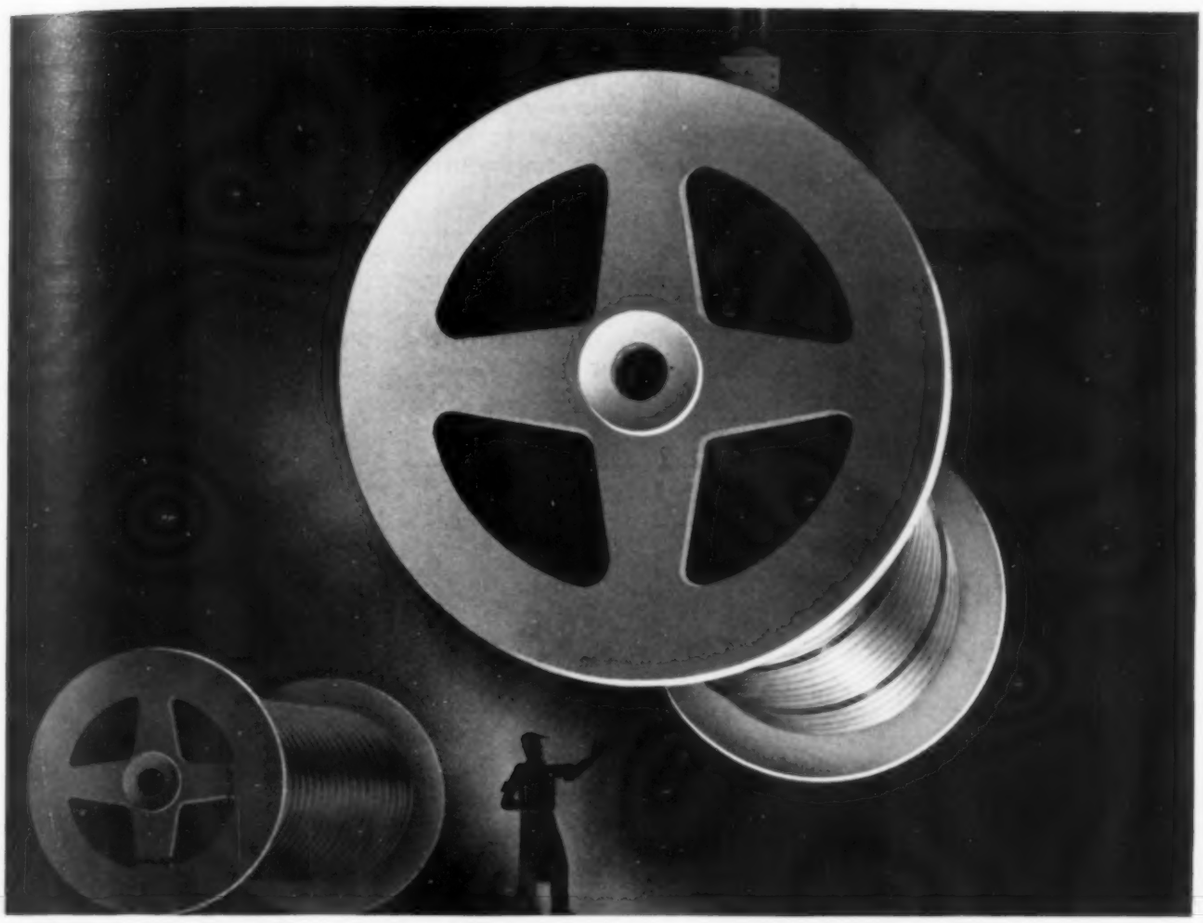
Awarded the John Fritz Gold Medal for 1938 by a board representing the American Society of Civil Engineers, American Institute of Mining and Metallurgical Engineers, American Society of Mechanical Engineers and American Institute of Electrical Engineers: **Paul D. Merica**, director of research, the International Nickel Co., Inc.

Howard Cousins has resigned from Crucible Steel Co. of America to accept a position in the sales department of the National Machinery Co., Tiffin, Ohio.

Elected to office by the Metal Treating Institute: **O. T. Muehlemeyer**, Rockford, Ill., president; **C. G. Heilman**, Commonwealth Industries, Detroit, vice-president; **Roy Lindbergh**, A. M. Lindbergh Co., Chicago, secretary-treasurer. To board of directors: **A. D. Bach**, president, New England Metallurgical Corp., Boston; **Kenneth Stumpf**, Stanley P. Rockwell Co., Hartford, Conn.; **A. M. Cox**, Pittsburgh Commercial Steel Treating Co., Pittsburgh; **Clifford Scott, Jr.**, C. U. Scott & Sons Co., Rock Island, Ill.

Robert C. Onan is now associated with Lindberg Engineering Co., Chicago.

George O. Pratt is now employed in the metallurgical division of the Aluminum Co. of America, New Kensington, Pa.



Cutting down reject percentages in difficult castings

• THE difficulties ordinarily encountered in bringing large castings of varying sections safely out of the mold have been strikingly demonstrated in one foundryman's experience with hoisting drums. With the usual carbon cast steel, the spokes had a tendency to pull away from the drum on cooling. Cracks and breaks brought the rejects to a discouraging percentage.

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MOLY

PERSONALS

Sheldon H. Reynolds is now in the metallurgical department of National Tube Co., National Works, McKeesport, Pa.

Transferred to the U.S. Patent Office as examiner of patents: **C. R. Cundiff**, formerly inspector of engineering materials, Naval Gun Factory.

In charge of all heat treating operations for Auburn Button Works, Auburn, N. Y.: **David W. Hitchcock**, formerly assistant heat treater for American Locomotive Corp., Diesel Engine Division.

Awarded the James Turner Morehead medal of the International Acetylene Association: **H. Sidney Smith**, consulting engineer, Union Carbide & Carbon Corp.

A. J. Wellings, lieutenant commander U.S.N., has been transferred from the metallurgical testing division, Naval Gun Factory, Washington, D. C., to U.S.S. California, as gunnery officer.

Arthur E. Broady, formerly metallurgist, process control department, Carnegie-Illinois Steel Corp., Chicago, is now metallurgist in the research department of the Midvale Co., Philadelphia.

Raymond F. Mann has formed the Wenz-Mann Co., western New York distributors for Reynolds Corp. and Lupton Steel Sash Co.

Howard F. Eilers has been made metallurgical engineer for the Joliet, Ill., plants of American Steel & Wire Co.

Stanley M. Baltzly, Jr. has been made sales representative in the Pittsburgh district for the Timken Steel and Tube Division of Timken Roller Bearing Co.

A. W. MacLaren is now employed in the metallurgical division of the Carnegie-Illinois Steel Corp., stationed in the Youngstown district.

William F. Boudreau has taken a position as junior analyst in the research division of the American Rolling Mill Co.

Appointed traffic manager of Basic Dolomite, Inc., Cleveland: **Ralph R. Shultz**, formerly traffic manager for White Motor Co.

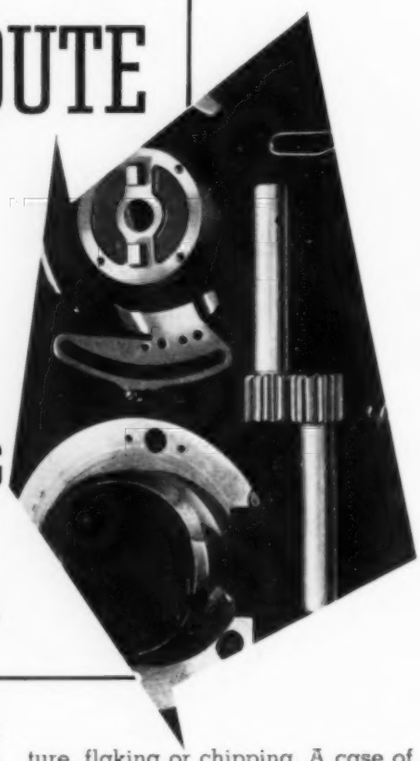
Miles C. Smith, formerly in charge of sales and marketing for Colmonoy, Inc., has resigned to direct sales promotion of Amercoat, a product of American Concrete and Steel Pipe Co., Los Angeles.

Puzant W. Bakarian is now connected with the Dow Chemical Co., Midland, Mich.

A NEW ROUTE

TO LOWER COSTS AND IMPROVED PRODUCTION

...VIA THE CHAPMANIZING PROCESS FOR SURFACE HARDENING



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SCALING OF CR-FE

(Starts on page 760)

an increase in carbon slightly decreases the oxidation resistance of the 10% chromium steels at all temperatures from 700 to 1100° C. (1300 to 2000° F.). Actual values vary from 2 to 90 units increase in weight for the alloy with 0.10% carbon as temperature rises from 700 to 1100° C., and these figures are reduced some 20% by increasing the carbon to 1.40%. Curves of weight-increase vs. carbon content show a slight minimum at about 1.0% carbon — a fact that is quite pronounced in the 20% chromium-irons.

In the latter series, scaling is about the same (and less than two units) for all carbon contents at 700 and 800° C. (1300 and 1475° F.), the structure of each being ferrite and carbide. At 900° C. (1650° F.) austenite appears in steels containing 0.80% carbon or more, which then show very little scaling in comparison with the low carbon steels of the same series at that temperature. This effect was intensified at 1000 and 1100° C. (1825 and 2000° F.). Representative figures are as shown in the tabulation for 1000° C. (1825° F.). Minimum scaling at 2000° F. (11 g./hr./m²) occurred in the 0.80% C alloy having a structure of austenite and carbide.

Carbon Content	Phases Present at 1825° F.	Increase in Weight
0.10	Ferrite	46 g./hr./m²
0.35	Ferrite and austenite	11
0.80	Ferrite and austenite	2
1.45	Austenite and carbide	5

All alloys containing 30% chromium contained ferrite and free carbide at all temperatures tested. Accordingly, scale resistance to hot air is quite different and decreases with increasing carbon content (that is, with increasing proportion of carbide) whereby the chromium content of the ferrite is correspondingly reduced. Reaction was quite slow in all cases, being 0.2 g. per hr. per sq.m. weight gain or less at 700° C. (1300° F.) and 2.5 units or less at 1100° C. (2000° F.).

In flue gas the scaling of the 10% chromium-iron alloy was about three times as great as in air, but it was independent of the carbon content. The 20% alloys were, however, considerably more resistant to flue gas than the 10% series, the corresponding figure for which at 1100° C. (2000° F.) was 250 g./hr./m².